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MANUAL OF SURGICAL ANATOMY

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A MANUAL
OF
SURGICAL ANATOMY

BY

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PREFACE TO THE THIRD EDITION REVISED.

In revising the text for this impression, the authors have made a number of relatively minor alterations, but the subject matter has not been expanded and the general plan of the book, which seems to have met with the approval of its readers, remains unaltered. Figures 132 and 134 have been redrawn for this impression, and the authors are grateful to Mr. J. E. Clapton for the care and skill which he has expended on them.

To those of their friends who have pointed out errors or inaccuracies, the authors desire to express their grateful appreciation.

L. B.
T. B. J.

London, 1930.

PREFACE TO THE THIRD EDITION.

In this edition the text has been generally revised, but the plan of the book as a whole has not been altered. A fuller description of the Sympathetic and Parasympathetic Systems has been included, and the section dealing with the components of sensory nerves and their repair after section has been expanded. Three of the older diagrams have been replaced by more detailed figures.

The authors are gratified by the friendly reception which has been accorded to the previous two editions, and consider that they have been justified in the view that there is a demand for a book which deals with the subject of Surgical Anatomy in a way that renders it suitable for use in the Dissecting Room and the Anatomical Museum.

To those of their friends who have pointed out inaccuracies or ambiguities in the last edition, the authors desire to express their grateful thanks, and they are particularly indebted to Mr. T. T. Stamm, who has been responsible for the revision of the index.

L. B.
T. B. J.

London; 1927.

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MANUAL
OF
SURGICAL ANATOMY.

THE SUPERIOR EXTREMITY.

THE SHOULDER REGION.

Surface Landmarks.—The **Clavicle** is the most important surgical landmark in this region. Its axis is directed downwards, forwards, and medially in well-developed subjects, but in poorly-developed individuals the bone assumes a horizontal position. The skin, superficial fascia, and platysma are all freely movable over its subcutaneous surface, and therefore compound fracture is a rare injury.

The large *sternal end* of the clavicle forms a rounded prominence immediately to the lateral side of the jugular (supra-sternal) notch and the sternal head of the sterno-mastoid. In its medial two-thirds the shaft is convex forwards and laterally, and this convexity is often greatly exaggerated in children with rickets. The lateral third is concave forwards, and on its anterior border there is a tubercle, of varying size, which is produced by the deltoid. The middle third forms the upper boundary of the superficial infra-clavicular triangle, which is not always a well-marked depression. Its distinctness depends on the proximity and development of the other borders, namely, the anterior margin of the deltoid and the upper margin of the clavicular head of the pectoralis major. On deep pressure in this triangle just below the clavicle, the pulsations of the first part of the axillary artery may be felt, and the vessel can be compressed downwards, backwards, and medially against the second rib.

The lateral border of the *acromial end* of the clavicle is marked by a weak ridge directed from before backwards, 1¼ inches medial to the lateral border of the acromion. When the acromio-clavicular ligaments are lax, it is possible to insinuate the finger-nail between the articular surfaces of the joint. An adventitious subcutaneous bursa is occasionally met with over this region in those accustomed to carrying heavy weights upon the shoulder.

The *coracoid process* of the scapula is not situated in the superficial infra-clavicular triangle, but lies under cover of the anterior border of the deltoid. It can be felt on direct backward pressure one inch below the clavicle near the junction of the lateral fourth with the rest of the bone.

The apex of the *acromion* is placed one quarter to half an inch in front of the acromio-clavicular joint. Its lateral border can be traced backwards for about two inches, till it joins the inferior border of the scapular spine, which meets it at the sharp *acromial angle*. When the upper arm is measured in suspected fracture of the humerus, the acromial angle is utilised instead of the acromion apex, the latter being more obscured by the deltoid. The subcutaneous upper surface of the acromion can be readily examined when the arm is supported in the abducted position, although the medial border is overlapped by the trapezius and the lateral by the deltoid.

The *spine of the scapula* can be traced medially and downwards to its flattened root opposite the third thoracic spine.

The superior border and the medial (superior) angle of the scapula are on a level with the second rib, but cannot be palpated easily, since they are under cover of the trapezius and the supra-spinatus. They can be examined if the upper fibres of the trapezius are relaxed by carrying the patient's arm as far as possible over the opposite shoulder.

The lower three-fourths of the *vertebral border*, the *inferior angle*, which lies over the seventh rib or seventh intercostal space, and the lower part of the *axillary border*, can all be palpated if the patient's forearm is carried behind his back so as to relax the trapezius, the rhomboids, and the latissimus dorsi.

The *anterior fold of the axilla* is formed by the lower border of the pectoralis major, which, at its medial attachment, follows the line of the fifth rib. A line, drawn from the lower margin of the sternal end of the clavicle to the lower limit of the insertion of this muscle, outlines the lower border of its clavicular head and indicates the plane of separation usually adopted in removal of the muscle in complete excision of the breast (Stiles).

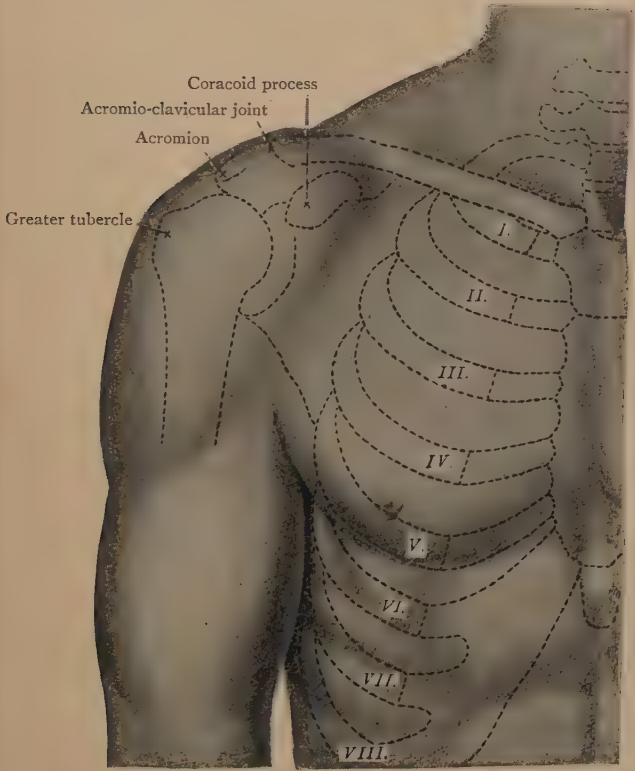

Coracoid process
Acromio-clavicular joint
Acromion
Greater tubercle
I.
II.
III.
IV.
V.
VI.
VII.
VIII.

FIG. 1.—Surface Landmarks of the Shoulder Region.

The **Deltoid**, with its wide V-shaped origin from the anterior border of the lateral part of the clavicle, the lateral border of the acromion, and the lower border of the scapular spine and its pointed insertion half-way down the lateral side of the humerus, is a conspicuous landmark. It overlies the greater tubercle (tuberosity), which is the most lateral bony point in the body, and so gives the shoulder its smooth convex contour.

Direct injuries around the *greater tubercle* of the humerus are often very difficult to diagnose, owing to the depth of the bone from the surface and to the bruising and effusion which supervene. An increase in the antero-posterior diameter of the greater tubercle can be determined by grasping that landmark between the fingers and thumb and comparing it with the greater tubercle of the opposite side. It is very suggestive of fracture in this part of the bone, but accurate diagnosis is possible only by means of the X-rays.

The *lesser tubercle* (*small tuberosity*) of the humerus points directly forwards and lies one inch lateral to the coracoid process and on a slightly lower plane. It also lies under cover of the deltoid. On deep pressure over them the tubercles can be felt to slip from under the finger, if the humerus is rotated alternately medially and laterally. Immediately to the lateral side of the lesser tubercle lies the *intertubercular sulcus* (*bicipital groove*) containing the long tendon of the biceps. This groove corresponds to the lower two-thirds of a line three inches long, drawn from the tip of the acromion down the arm in the axis of the humerus.

When the arm is by the side, the inferior margin of the head of the humerus is easily palpated through the floor of the axilla. As the arm is abducted, more of the head becomes exposed to the examining finger, but it is less distinctly felt owing to the tightening of the axillary fascia.

Superficial Nerves.—The skin of the shoulder region is supplied in front by the *descending branches of the cervical plexus* (C. 3 and 4).

The anterior and middle supra-clavicular branches (suprasternal and supra-clavicular) extend down on to the chest wall as far as the second intercostal space, where they are overlapped by branches from the second intercostal nerve. This fact explains the constant level of the anterior *line of anæsthesia* in fracture dislocations occurring between the fifth cervical and second thoracic vertebræ, and also the referred pain sometimes felt over the clavicle in Pott's disease of the third, fourth, and fifth cervical vertebræ. Occasionally the supra-clavicular nerves are involved in callus following fracture of the clavicle and cause persistent neuralgia, which may radiate over the same side of the head and neck. The posterior supra-clavicular (supra-acromial) branches extend down for a short distance over the deltoid, overlapping the cutaneous branches of the axillary (circumflex) nerve (Fig. 2).

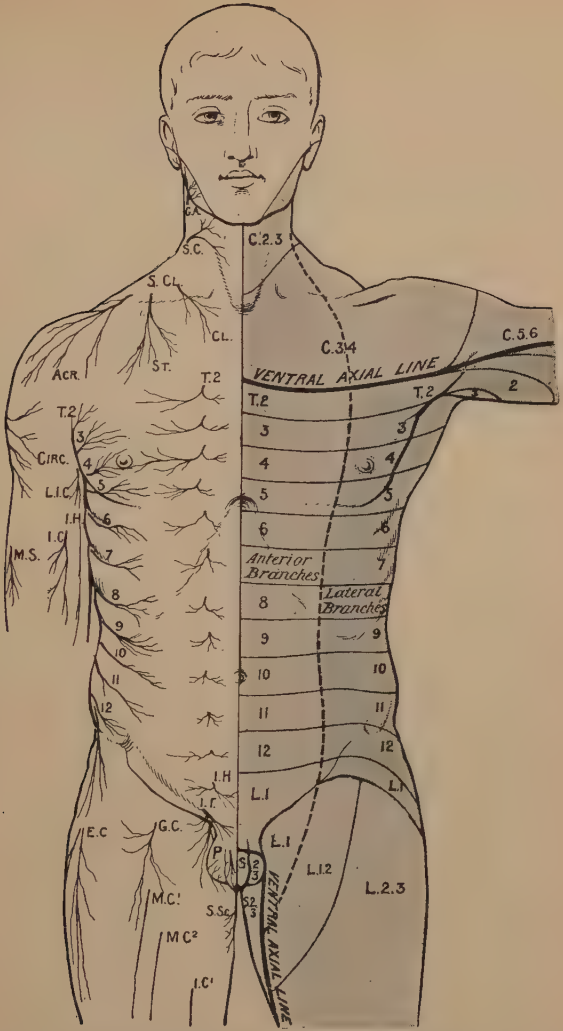

G.A
S.C.
S.CL.
CL.
ACR.
ST.
T.2
C.2.3
C.3.4
C.5.6
VENTRAL AXIAL LINE
T.2
2
T.2
T.2
3
3
3
CIRC.
4
4
4
5
5
5
L.I.C.
I.H
6
6
6
I.C
M.S.
Anterior Branches
7
7
Lateral Branches
8
8
9
9
9
10
10
10
11
11
11
12
12
12
I.H
I.I.
L.1
L.1
G.C.
E.C
L.1
P
S
2 3
L.1.2
L.2.3
M.C¹
S.Sc
S2 3
VENTRAL AXIAL LINE
MC²
I.C¹

FIG. 2.—The Nerve Supply of the Skin on the Ventral Aspect of the Trunk. The whole of the area shown in the diagram is supplied by branches from the anterior rami (primary divisions) of the spinal nerves.

G.A, Great auricular nerve; S.C, N. cutaneus colli; S.CL, Supra-clavicular nerves; ACR, Posterior; ST, Middle; CL, anterior; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; CIRC, Cutaneous branch of axillary nerve; L.I.C, Medial cutaneous nerve of the arm (O.T. lesser internal cutaneous nerve); I.H, Intercosto-brachial; I.C, Medial cutaneous nerve of the forearm (O.T. internal cutaneous); M.S, Cutaneous branch of radial nerve; E.C, Lateral cutaneous nerves; G.C, Lumbo-inguinal nerve; M.C^{1} ^{2}, Intermediate cutaneous nerves; I.C^{1}, Branch of medial cutaneous nerve; P, Branches of pudendal nerve; S.Sc, Branches of posterior cutaneous nerve of the thigh.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

Referred pain occurs in the shoulder region in diaphragmatic pleurisy and, on the right side, in tropical abscess of the liver and, more rarely, in pathological conditions of the gall-bladder. The stimuli reach the fourth cervical segment *via* the phrenic nerve (p. 246).

Anteriorly, as already mentioned, the skin is supplied entirely by C. 3 and C. 4, but the skin of the corresponding area on the *dorsal aspect* is supplied by the fourth to the sixth cervical and the upper three thoracic nerves (Fig. 3). From this it will be seen why, in fracture dislocations below the fourth cervical vertebra, the line of anæsthesia is higher on the posterior than on the anterior aspect of the body.

Below the shoulder, *i.e. over the floor of the axilla*, the skin is supplied by the lateral cutaneous branches of the second (intercosto-brachial, p. 32) and third intercostal nerves.

Superficial Veins.—The *cephalic vein* runs upwards in the groove between the deltoid and the pectoralis major, and passes backwards through the superficial infra-clavicular triangle to join the axillary vein. It frequently communicates with the external jugular by means of a small vein which crosses in front of the clavicle (Fig. 35). This vessel becomes considerably enlarged in those cases of excision of the breast in which a portion of the axillary vein has been excised, as it offers an efficient channel for the venous return from the limb.

Trapezius.—The origin of this muscle extends from the occipital bone above to the lowest thoracic spine. The *upper fibres* are attached to the posterior border of the clavicle in its lateral half. They support the clavicle, and, through it, part of the weight of the upper limb. The *lower part* of the muscle is inserted into the medial border of the acromion and the upper border of the spine of the scapula. A bursa is situated between the muscle and the flattened root of the scapular spine. The muscle is supplied by the (spinal) accessory nerve and by branches from C. 3 and C. 4. The upper fibres elevate the point of the shoulder and the others reinforce the movement by rotating the scapula so that the inferior angle passes forwards. In producing the latter movement it helps the serratus anterior (s. magnus) (p. 31) to raise the arm above the head. Injury to the accessory nerve, with paralysis of the trapezius, causes the point of the shoulder on the affected side to fall to a lower level.

Sterno-Clavicular Joint.—The line of the joint passes

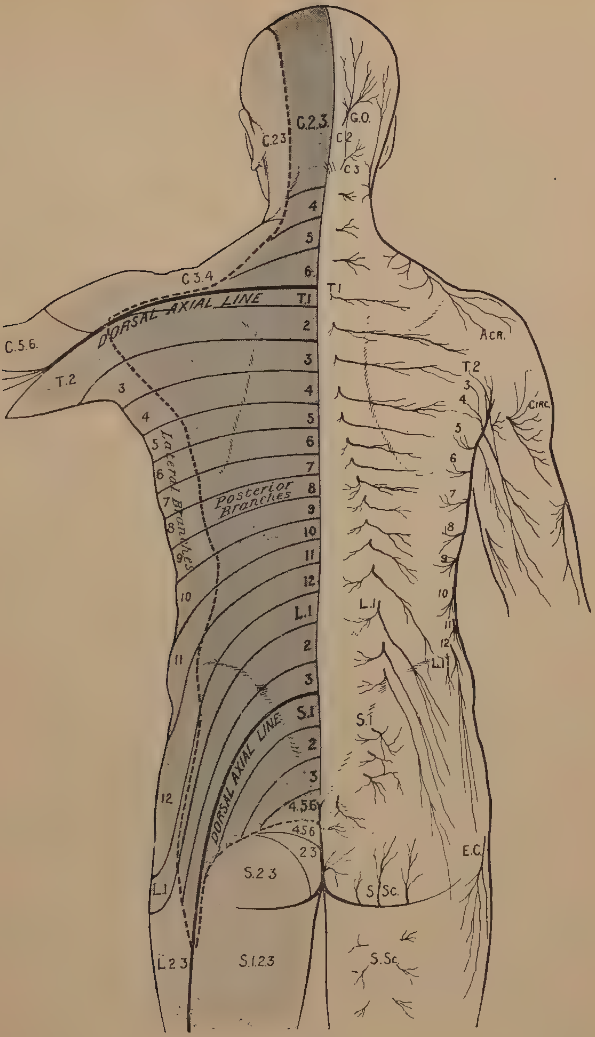

C.2.3.
C.23
G.O.
C2
C3
4
5
6
C3.4
T.I
DORSAL AXIAL LINE
T.I
2
3
4
5
6
7
8
9
10
11
12
L.I
2
3
S.I
2
3
4.5.6
456
23
ACR.
C.5.6.
T.2
3
4
5
6
7
8
9
10
11
12
CIRC.
Lateral Branches
Posterior Branches
T.2
3
4
5
6
7
8
9
10
11
L.I
12
L.I
S.I
DORSAL AXIAL LINE
12
L.I
E.C.
S.2 3
S Sc.
L.2 3
S.I.2.3
S.Sc.

FIG. 3.—The Nerve-Supply of the Skin on the Dorsal Aspect of the Trunk. The dotted line indicates the limits of the area supplied by the posterior rami (primary divisions) on the left side of the body.

G.O.	Greater occipital nerve.	E.C.	Lateral cutaneous nerve of thigh.
ACR.	Posterior supra-clavicular nerves.	S.Sc.	Posterior cutaneous nerve of thigh.
CIRC.	Cutaneous branches of axillary nerve.		

from above downwards and laterally. The articular surface of the clavicle, the more mobile bone, is larger than the sternal facet, and, below, it comes into contact with the first costal cartilage. A somewhat loose capsule, lined with synovial membrane, is attached to the margins of the articular surfaces. It is thickened in front and behind by the anterior and posterior sterno-clavicular ligaments. Anteriorly, the sterno-clavicular joint is covered by the sternal head of the sterno-mastoid, and,

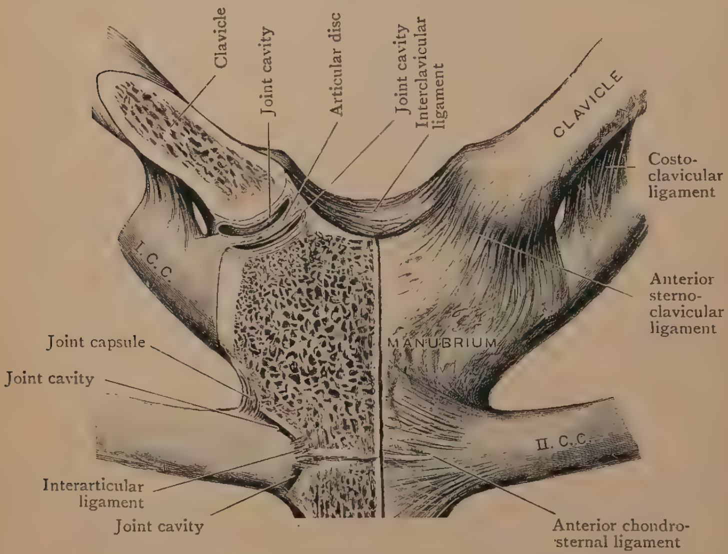

Clavicle
Joint cavity
Articular disc
Joint cavity
Interclavicular ligament
CLAVICLE
Costo-clavicular ligament
I. C.C.
Anterior sterno-clavicular ligament
MANUBRIUM
Joint capsule
Joint cavity
II. C.C.
Interarticular ligament
Joint cavity
Anterior chondro-sternal ligament

FIG. 4.—Sterno-Clavicular and Costo-Sternal Joints.

posteriorly, it is in relation to the sterno-hyoid and the sterno-thyreoid muscles.

The joint is divided into a medial or inferior and a lateral or superior compartment by a disc-shaped meniscus, which is attached to the clavicle above, the first costal cartilage below, and to the capsule in front and behind. When the arm is hanging by the side the upper compartment is V-shaped, but when the arm is raised the upper part of the disc is thrust medially by the clavicle, and both compartments become slit-like. The disc acts as a buffer between the clavicle and the sternum and serves to diminish the results of indirect violence.

Two accessory ligaments strengthen the joint: (1) The *inter-clavicular ligament*, which stretches from clavicle to clavicle across the upper surface of the capsule and dips down in the centre to become attached to the jugular (supra-sternal) notch; (2) The *costo-clavicular* (*rhomboid*) *ligament*, which connects the under surface of the sternal extremity of the clavicle to the upper surface of the first costal cartilage.

Movements.—The sterno-clavicular joint acts as a hinge for the clavicle, so that when the acromial end of the bone is elevated or depressed, carried forwards or backwards, the sternal end passes in the opposite direction. In *elevation* or *depression* of the point of the shoulder the sternal end of the clavicle moves over the surface of the articular disc, but when the shoulder is *thrust forwards* or *backwards* the disc moves with the clavicle over the clavicular facet on the sternum. Excessive upward movement of the shoulder is checked by the tension of the costo-clavicular ligament, and the opposite movement by the tension of the articular disc and the inter-clavicular ligament.

The *anterior supra-clavicular* (*supra-sternal*) *nerves* (C. 3 and 4) supply the joint, and *branches from the internal mammary* and the *clavicular branch of the thoraco-acromial* (*thoracic axis*) artery anastomose around it.

In **Dislocations of the Joint** the sternal end of the clavicle usually passes forwards, tearing the anterior sterno-clavicular ligament. The direction taken by the bone is said to be due to the weakness of this ligament, but it is more probable that it depends on the application of the force along the axis of the clavicle. Though this dislocation is easy to reduce by pulling the two shoulders backwards, it is difficult to retain the bones in apposition owing to the normal obliquity of their articular surfaces.

Backward dislocation is rare, and is caused either by indirect force thrusting the shoulder forwards, or by direct violence from in front at the sternal end of the clavicle. In this injury the posterior sterno-clavicular ligament is torn, and the clavicle passes backwards, downwards, and medially, and may compress the innominate vein, the trachea, or on the left side, the œsophagus.

Dislocation upwards is especially resisted by the articular disc and the inter-clavicular ligaments. When these ligaments are torn, the sternal end of the clavicle passes into the jugular (supra-sternal) notch between the sterno-mastoid anteriorly (p. 8) and the sterno-hyoid and sterno-thyreoid posteriorly.

The sterno-clavicular joint is not infrequently the seat of suppuration in pyæmia. One or both compartments may be involved and the pus usually perforates the anterior ligament. Should it perforate the posterior ligament, it will find its way down between the two pleural sacs into the superior mediastinum, following the course of the innominate vein.

On the right side, the joint may be involved in aneurism of the innominate artery, which lies immediately behind it.

Acromio-Clavicular Joint.—The articular surfaces of the two bones are oblique and the plane of the joint passes downwards and medially. A weak capsule, thickened above and below, is attached to the articular margins. A wedge-shaped disc protrudes into the joint cavity from the upper part of the capsule; the disc is covered and the capsule is lined with synovial membrane. The joint is strengthened by the accessory *conoid* and *trapezoid bands*, which together form the **coraco-clavicular ligament** and bind the upper surface of the coracoid process to the under surface of the clavicle near its acromial end. Part of the weight of the upper limb is conveyed to the clavicle along this ligament which, in addition, serves to retain the two bony elements of the shoulder-girdle in close apposition during rotation of the scapula.

A gliding antero-posterior movement occurs at the acromio-clavicular articulation, so that, when the shoulder is thrust forwards, the angle between the clavicle and the upper border of the spine of the scapula becomes smaller.

The obliquity of the articular surfaces serves to explain the common injury of *upward dislocation* of the clavicle. Any force directed medially or downwards on to the acromion will thrust it beneath the clavicle, tearing the superior ligament of the joint. The reverse dislocation is extremely rare. A much exaggerated displacement in either dislocation indicates rupture of the coraco-clavicular ligament.

The **Clavicle** fulfils the functions of a prop and keeps the acromion and, through it, the shoulder-joint at a constant distance from the trunk, to which it transmits a part of the weight of the upper limb. The trapezius supports its acromial end and counteracts the downward pull of the weight of the arm. The clavicle is exposed more often to violence than any other bone in the body and, for that reason, is very commonly injured. These injuries may take the form of fractures, dislocations, or separation of the epiphysis.

Ossification.—The clavicle is the first bone in the body to ossify (fifth week), and the primary centre forms the shaft and the acromial end. A secondary centre appears at the sternal end at about the twentieth year and fuses with the shaft about the twenty-fifth. Congenital absence of both clavicles is rare, but from accounts of the recorded cases the functional disability is slight.

Excision of the Clavicle.—Removal of the *Middle Third* of the clavicle is commonly carried out as a preliminary step in interscapulo-thoracic amputation, as it facilitates ligature of the third part of the subclavian artery. The *Whole Bone* may be excised most easily from acromial to sternal end.

Examination of the Clavicle.—In suspected injury of the clavicle or of the acromion the surgeon stands behind the patient and compares the contours of the two shoulders. He next places a hand on each side of the neck in such a way that the tips of the fingers palpate the jugular (supra-sternal) notch and the thumbs rest behind on the vertebral spines. The hands are separated from one another so that the fingers pass over the subcutaneous surfaces of the two clavicles. When the acromio-clavicular joint is reached the fingers are carried forwards around the anterior extremity of the acromion, and its subcutaneous surface and lateral border may be palpated.

Fractures of the Clavicle.—Fracture of the sternal end of the clavicle, medial to the costo-clavicular (rhomboid) ligament, is rare, and the displacement is not great unless the costo-clavicular ligament is torn. When this occurs, the medial end of the lateral fragment is tilted upwards by the sterno-mastoid and the acromial end of the clavicle sinks downwards owing to the weight of the arm.

The *common site of fracture* is the point of union of the middle and lateral thirds, where the bone is weak owing to the junction of its two curves. It is the commonest of all fractures. One third of the cases are of the greenstick variety and occur in infancy. It is generally due to indirect violence from falls on the hand, elbow, or shoulder, and the force is transmitted to the clavicle through the glenoid cavity and the coraco-clavicular ligament, or through the acromion. The direction of the fracture is most constant—it is downwards, medially, and forwards. The displacement of the lateral fragment is in the same direction, and the limb collapses medially and forwards on to the trunk, consequent on the snapping of its prop. The medial fragment is tilted upwards by the sterno-mastoid. It is rare to find any injury to the subclavian vessels or to the nerves of the brachial plexus, which all lie behind and below the clavicle, because they are protected by the subclavius muscle, which acts as a cushion between them and the broken bone. Occasionally, the lateral fragment is displaced backwards by direct violence from in front. In this case the transverse scapular (supra-scapular) and transverse cervical (transversalis colli) veins (p. 135) may be injured.

Fracture of the acromial end of the shaft may occur between the attachments of the two parts of the coraco-clavicular ligament from direct violence, in which case there is little displacement, or it may occur lateral to the ligament, in which case the lateral fragment tends to turn medially and forwards. The point of the shoulder is rotated medially and sinks slightly.

In *children*, fractures of the clavicle are usually of the greenstick variety, as the bone is soft and its enveloping periosteum is exceedingly strong.

The Vertebro-Scapular Muscles.—The *Trapezius* (*see* p. 6).

The *Levator Scapulæ* is attached to the medial (superior) angle of the scapula, and is supplied by C. 3 and 4 (p. 134).

The *Rhomboid Minor* and *Major* arise from the upper thoracic spines and are inserted into the vertebral border of the scapula. The dorsalis scapulæ nerve (nerve to the rhomboids) (C. 5) runs down along the vertebral border of the scapula under cover of the three above-mentioned muscles. (The results of injury to this nerve are described on p. 99.) It is accompanied by the descending (posterior scapular) branch of the transverse cervical artery, which anastomoses on the scapula with the subscapular (p. 34) and the transverse scapular (supra-scapular) arteries (p. 147).

These three muscles rotate the scapula so that the inferior angle passes backwards and medially, and they are the antagonists of the trapezius and the serratus anterior (p. 31). The scapula is retained in its normal position by the balance between these opposing groups.

The Scapula.—**Ossification** begins in the fœtal scapula during the second month. The most important secondary centre forms the greater part of the coracoid process. It appears during the first year and joins the body about the eighteenth year. Cases of ununited coracoid epiphyses have been recorded, but the condition is very rare.

Two secondary centres appear about the tenth year to form the acromion, and join the spine of the scapula about twenty-five. This epiphysis fails to fuse in 10 per cent of subjects, and the condition is usually bilateral. The line of non-union is transverse and is at right angles to the axis of the acromio-clavicular joint. The acromion is generally attached to the spine by fibrous tissue, but occasionally a complete joint is present. The presence of a movable acromion, together with a history of injury to the shoulder region, is apt to suggest a fracture. The symmetrical character of ununited acromial epiphysis is of great value in the differential diagnosis.

A sub-coracoid centre, which forms part of the base of the coracoid and the upper part of the glenoid cavity, appears at ten and fuses at seventeen. The margin of the glenoid cavity inferiorly is formed by a secondary centre which appears at seventeen and fuses soon after. The other secondary centres have little surgical importance.

Fractures of the Scapula are uncommon because the bone is well protected by muscles. The commonest variety is fracture of the body, generally through the infra-spinous fossa. The spine and coracoid process, which belong to the upper fragment, may be gripped with one hand, and the inferior angle, which belongs to the lower fragment, with the other. Preternatural mobility and crepitus may be determined by moving the hands in opposite directions.

If the surgical neck, which extends from the scapular notch to a point on the axillary border just below the glenoid cavity, is fractured, the surgeon can grasp the spine and acromion with one hand and the head of the humerus with the other. Crepitus may sometimes be elicited, through the medium of the capsule of the shoulder-joint, by moving the head of the humerus backwards and forwards.

Fracture of the Coracoid is rare, and up to seventeen may be of the nature of a separation of the epiphysis. There is little displacement, unless the coraco-clavicular ligament, which holds it up, is torn. Laterally, the coracoid is steadied by the coraco-acromial ligament, and medially, by the pectoralis minor. It is drawn downwards by the weight of the arm and by the coraco-brachialis and the short head of the biceps, which are attached to its tip.

In complete excision of the scapula for malignant disease, a preliminary ligature of the subscapular vessels and myotomy of the muscles attached to the coracoid process may be performed through an incision along the medial border of the coraco-brachialis.

The **Coraco-Acromial Ligament** passes from the lateral border of the coracoid process to the acromion just in front of the acromio-clavicular joint. It forms a strong arch above the shoulder-joint, and helps to prevent upward dislocation of the head of the humerus.

The **Sub-acromial Bursa** lies between the deltoid, the acromion and the coraco-acromial ligament above, and the capsule of the shoulder-joint and the muscles attached to it below. It very rarely communicates with the joint, but owing to its position, pathological conditions of the bursa may be mistaken for articular affections. The sub-acromial bursa serves as a soft pad between the humerus and the acromion, but when it is distended with fluid or when the walls are thickened by chronic inflammation (Codman's bursitis), movements of the humerus become painful, especially the movement of abduction, which crushes up the bursa against the acromion. Pus from an abscess of this bursa gravitates either to the anterior or to the posterior border of the deltoid.

The **Deltoid** (p. 3) continues and maintains the movement of abduction of the humerus, after it has been initiated by the supra-spinatus. In complete abduction the humerus can be raised to an angle of nearly 180°, but the deltoid is responsible for only half of that amount. The rest is effected by rotation of the scapula under the action of the trapezius and the serratus anterior (p. 31). The clavicular fibres are flexors and medial rotators of the humerus ; the posterior fibres have the opposite actions. The muscle overlies the shoulder-joint and the tendons in relation to it, and is supplied by the axillary (circumflex) nerve (C. 5 and 6), which enters its deep surface.

The Deep Fascia on the Dorsal Scapular Muscles.—The deep fascia is strong and dense over the supra-spinatus and infra-spinatus muscles, and is attached to the borders of the scapular fossæ. It is weakened above the superior transverse scapular (supra-scapular) ligament, where the transverse scapular vessels enter the fossa, and also at a point half-way down the axillary border, where the circumflex scapular (dorsalis scapulæ) vessels pass on to the dorsum.

Pus originating in the infra-spinous fossa is prevented from passing backwards by the strong fascia. It follows the circumflex scapular (dorsalis scapulæ) vessels and gravitates down to point at the lower part of the posterior fold of the axilla. In the supra-spinous fossa it generally passes through or over the scapular (supra-scapular) notch and points, near the coracoid process, under the anterior border of the deltoid ; or, it may gravitate into the infra-spinous fossa ; or, very rarely, it may make its way through the supra-spinous fascia and the trapezius and point in the angle between the clavicle and the spine of the scapula.

The *Supra-spinatus* arises from the supra-spinous fossa, and is inserted into the upper surface of the greater tubercle of the humerus. It passes immediately above the shoulder-joint and is partly inserted into the capsule. It initiates the movement of abduction and assists the deltoid.

The *Infra-spinatus* arises from the infra-spinous fossa, and is inserted into the postero-superior surface of the greater tubercle. It passes over the posterior surface of the shoulder-joint and partially blends with the capsule; it is the chief lateral rotator of the humerus.

Both these muscles are supplied by the supra-scapular nerve (C. 5 and 6), which passes through the scapular notch below the ligament. (The results of injury to this nerve are described on p. 100.)

The *Teres minor* lies in relation to the lower part of the posterior aspect of the capsule of the shoulder-joint, and its action is the same as that of the infra-spinatus. It is supplied by the axillary (circumflex) nerve (C. 5 and 6).

Ossification of the Proximal Extremity of the Humerus.—At birth the proximal extremity of the humerus is entirely cartilaginous. During the first year a secondary centre appears for the *articular head* of the bone; at the second year, one appears for the *greater tubercle*; at the end of the third year, one appears for the *lesser tubercle*. These three centres unite to form the proximal epiphysis of the humerus during the seventh year. It fits like a cap over the proximal end of the diaphysis, which is somewhat pointed (Fig. 5), and it fuses with the diaphysis between eighteen and twenty-five. The epiphyseal line passes distal to the tubercles, but on the medial side it coincides with the margin of the articular head of the bone.

Ossification of glenoid cavity (p. 13).

The Shoulder-Joint.—The articular surface of the glenoid cavity is slightly concave and is small in comparison with the head of the humerus, which forms a large convex surface, directed upwards, medially, and slightly backwards. The glenoid cavity is enlarged and deepened by the labrum glenoidale (glenoid ligament), which is attached to its margins.

The **Capsule**, which is very large and remarkably loose, obtains a wide range of movement for the joint. Proximally, it is attached to the labrum glenoidale, and above, to the bone immediately beyond the origin of the long head of the biceps. On the humerus it is attached to the anatomical neck, laterally, but to the surgical neck, on the medial side. The line of attachment of the capsule crosses the epiphyseal line, so that *the lateral portion of the epiphysis (the tuberosities) is extra-capsular, while the medial part of the proximal end of the diaphysis is intra-capsular.*

The capsule is strengthened anteriorly by the three *gleno-humeral ligaments*, and above by the *coraco-humeral ligament*. These accessory bands blend with the capsule so closely that it is impossible to separate them from it. Additional support is received from the subscapularis in front, the supra-spinatus above, and the infra-spinatus, and to a lesser degree the teres minor, behind. Inferiorly, the capsule pouches downwards when the arm is by the side, an arrangement which permits of free abduction. It is here intimately related to the quadrilateral

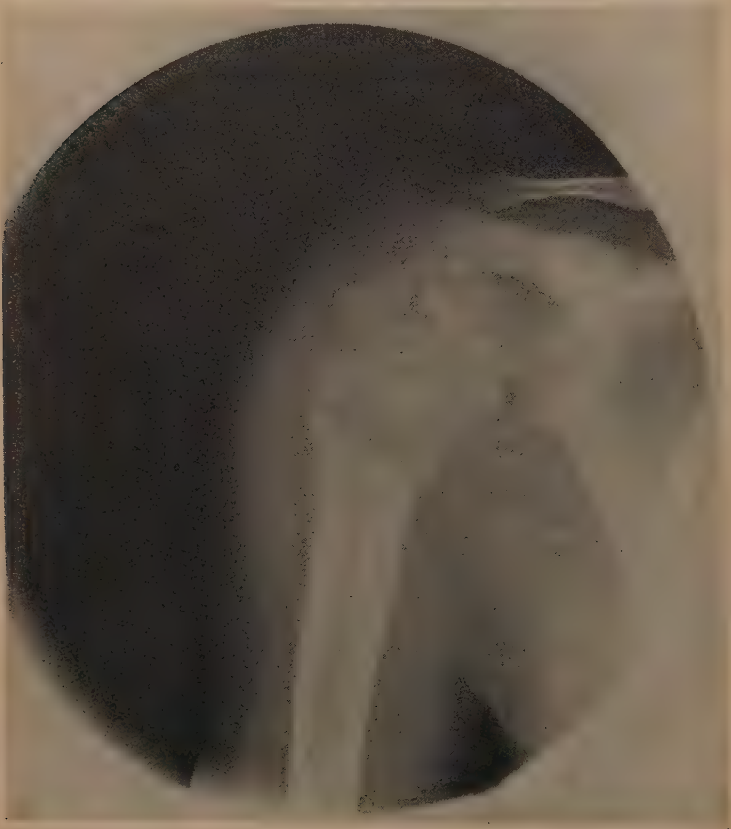


FIG. 5.—Shoulder of a Child, aged six. Antero-posterior view. The centre of ossification for the greater tubercle has not yet fused with the centre for the head of the humerus. The radiogram shows a fracture through the surgical neck of the bone. Compare the position of the head of the humerus with that shown in Fig. 7.

space (p. 39), and the structures passing through it (Fig. 6). Stiffness of the shoulder, following reduction of dislocations, may be due to the formation of adhesions between the contiguous synovial surfaces of this part of the capsule. Early massage and passive movement will prevent such a complication.

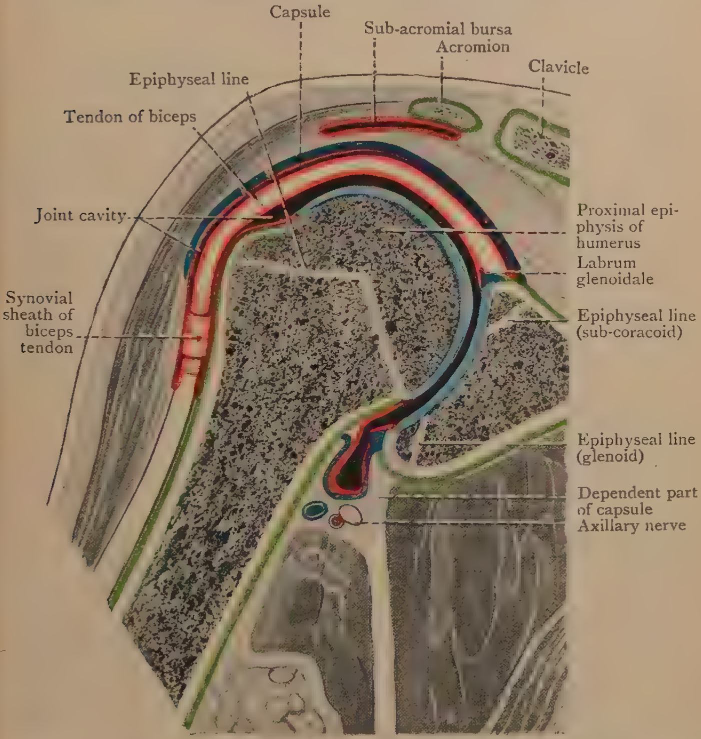

Capsule
Sub-acromial bursa
Acromion
Clavicle
Epiphyseal line
Tendon of biceps
Joint cavity
Proximal epiphysis of humerus
Labrum glenoidale
Epiphyseal line (sub-coracoid)
Synovial sheath of biceps tendon
Epiphyseal line (glenoid)
Dependent part of capsule
Axillary nerve

FIG. 6.—Frontal Section through the Right Shoulder-Joint. The parietal and visceral layers of the synovial sheath of the biceps tendon have been partially left in place.

Light blue = articular cartilage. Green = periosteum.
Dark blue = ligaments. Red = synovial membrane.

The **Synovial Membrane** lines the capsule and is attached to the articular margins of the two bones. It covers, but is not adherent to, the periosteum over the intra-capsular part of the neck of the humerus (intra-capsular part of diaphysis and epiphyseal cartilage, in the young). Between the superior and middle gleno-humeral ligaments there is an opening in the capsule. The synovial membrane of the joint herniates through this opening to form a bursa, which is situated between the subscapularis in front and the neck of the scapula and the capsule behind. A similar bursa, communicating with the joint, may occasionally be found between the capsule and the tendon of the infra-spinatus.

The *long head of the biceps* arises from the highest point on the glenoid margin and traverses the joint. But although it is intra-capsular, it remains extra-synovial as it receives a tubular sheath from the synovial membrane (Fig. 6), which invests the tendon for a varying distance after it has left the capsule. This synovial sheath and the tendon are retained in the inter-tubercular sulcus by the *transverse ligament*—a special slip of the capsule, which bridges the groove and is attached to both tubercles. This ligament is occasionally torn by violent muscular efforts, and when that occurs the tendon of the biceps becomes displaced to the medial side of the lesser tubercle. Until the tendon is replaced by the movement of abduction, the forearm cannot be completely extended (Thomson and Miles).

The *nerve-supply of the joint* comes from the supra-scapular and axillary (circumflex) nerves (C. 5 and 6).

Around the surgical neck of the humerus an arterial ring is formed by the anterior and posterior circumflex arteries, which send branches proximally to supply the joint. These anastomose with twigs from the thoraco-acromial (thoracic axis), which descend from above, and with an ascending branch from the (superior) profunda (p. 43).

The presence of fluid within the joint may be appreciated in the neighbourhood of the long head of the biceps, because it gravitates down the synovial sheath which surrounds the tendon. When the subscapularis bursa is involved, the swelling may be felt high up on the posterior wall of the axilla. The joint is best *aspirated* by pushing the needle backwards through the deltoid and the subscapularis at a point a quarter of an inch medial to the lesser tubercle, which serves as a convenient bony landmark. In this way the great vessels and nerves and the sub-acromial bursa are all avoided.

Spread of Tuberculous Disease in the Shoulder Region.—When tuberculous disease originates in the head or neck of the scapula, it readily spreads to the joint through the articular cartilage, because the epiphyseal cartilages of the secondary centres for the glenoid cavity only exist near its margin (p. 13).

If the disease begins in the proximal end of the diaphysis of the humerus and spreads either *forwards*, *backwards*, or *laterally*, it will in time perforate the periosteum and infect the overlying soft parts. Should it spread *medially*, it will perforate the periosteum covering the intra-capsular part of the diaphysis (Fig. 6). The infection will then be intra-capsular but extra-synovial. The synovial membrane rapidly becomes involved and the joint infected. If the disease spreads *upwards*, it must involve the epiphyseal cartilage and epiphysis before it can break through the articular cartilage into the joint. Lastly, it may travel distally and infect the medullary cavity.

Surgical Approach to the Shoulder-Joint.—In *Empyæma* of the joint, good access is obtained by a vertical incision, made midway between the coracoid process and the acromion. The anterior fibres of the deltoid are separated and the distended capsule, which is then exposed, can be incised. A pair of dressing forceps may be passed through the joint and made to project posteriorly below the tendon of the teres minor. The instrument may then be cut down upon from behind and a drainage tube drawn through. A horizontal incision is employed in order to avoid injuring the axillary (circumflex) nerve.

In *Tuberculous Disease* the joint may be approached either from the anterior or from the posterior aspect. The latter route, though more difficult, gives the better access (Kocher). In the *anterior method* the approach is direct, and little damage is done either to the deltoid or to its nerve of supply. By rotating the humerus first medially and then laterally, it is possible to elevate the muscles from the greater and lesser tubercles, either sub-periosteally or sub-cortically, depending on the age of the patient. The head of the humerus may be removed through a comparatively small incision, but if the glenoid cavity and neck of the scapula require to be excised, it is not easy to remove them by the anterior route.

The *posterior method* of approach affords a much more extensive view of the articulation. This is obtained by freeing the trapezius and the deltoid from the spine of the scapula, by sawing through the spine obliquely into the great scapular notch, and by rotating forwards the acromion and the deltoid. The capsule is opened above, where, according to Kocher, the subsequent weakness matters least.

Dislocation of the Shoulder.—In the child, the capsule is stronger than the bond of union between the diaphysis and epiphysis, and consequently the common injury is a separation of the proximal epiphysis. In the adult, the shoulder-joint is ligamentously and osseously weak, and is strong only by virtue of its muscular support. Stability is sacrificed for mobility, and, as a result, dislocation of the joint is exceedingly common.

The violence which causes the dislocation is unexpected, and the supporting muscles are consequently relaxed at the time of the accident. The humerus is generally in the abducted position and forms the long arm of a lever, whose short arm is formed by the head of the bone. The acromion acts as a fulcrum, and when the long arm of the lever is thrust upwards, the head is tilted downwards upon the inferior part of the capsule, which is the only area unsupported by muscular insertions. This gives way, and the head of the bone passes through the tear and lies below the glenoid cavity. It therefore enters the quadrilateral space, where it at once comes into relation with the axillary (circumflex) nerve, which is occasionally bruised or even ruptured, although it usually slips over the smooth convex surface of the head of the humerus without suffering injury.

The head may remain in this position—**the sub-glenoid dislocation.** The lower margin of the glenoid rests in the groove of the anatomical neck, and the head lies between the long head of the triceps behind and the subscapularis in front.

Though all dislocations are, in the first instance, sub-glenoid, the flexors and adductors of the shoulder usually draw the head of the humerus upwards, forwards, and medially. This is the anterior displacement, and the head of the bone may occupy any of the following positions :

1. **The Sub-coracoid.**—This is the commonest dislocation. The humeral head lies behind the subscapularis and in front of the neck of the scapula. The articular surface is directed somewhat forwards, and the humerus is laterally rotated owing to the stretching of the infra-spinatus and the teres minor. The posterior part of the capsule is stretched across the articular surface of the glenoid cavity.

2. **The Intra-coracoid.**—The anatomical neck rests on the anterior surface of the neck of the scapula. The lateral rotators are over-stretched, and if they do not rupture, a part or the whole of the greater tubercle is torn away, and the subscapularis, being unopposed, rotates the humerus medially.

3. **The Sub-clavicular.**—The head of the humerus rests on the subscapular fossa, and it can reach this position only after extensive laceration of the capsule and the muscles.

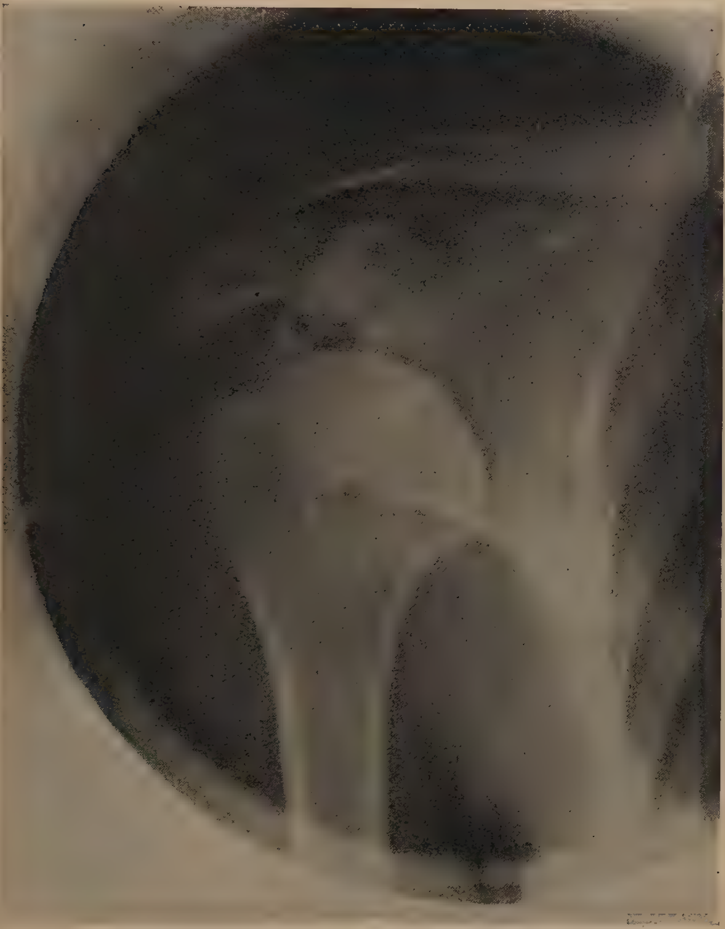


FIG. 7.—Sub-coracoid dislocation of Shoulder-Joint in an Adult Female. The acromion projects beyond the greater tubercle, while the shadows thrown by the glenoid fossa and the upper part of the axillary border of the scapula are partially obscured by the head of the humerus, above which the foreshortened coracoid process can be recognised.

In the **Posterior Displacements** the head of the humerus rests on the posterior margin of the glenoid cavity, or on the neck of the scapula, or in the infra-spinous fossa. The infra-spinatus is usually stripped up by the head of the bone, and the nature of the rotation of the humerus depends on whether the subscapularis is ruptured or remains intact.

In all dislocations of the shoulder the normal rounded contour is lost, as the greater tubercle is drawn medially. For the same reason the lateral border of the acromion, now the most lateral bony point in the region, becomes more prominent, and a straight edge can be made to touch both the acromion and the lateral epicondyle of the humerus. In the anterior displacements the head of the humerus produces a rounded elevation, which may occlude the superficial infra-clavicular triangle. This deformity is more pronounced in the sub-clavicular variety.

Miller's Method of Reduction.—The initial steps, which consist of abduction and traction on the arm, draw the head of the humerus free from the scapula, relax the deltoid and supra-spinatus, and stretch the lower part of the capsule and the subscapularis. If the tear involves the anterior part of the ligament, reduction may occur without further manipulation, as in Kocher's method (*vide infra*). If the tear is confined to the inferior aspect of the capsule, the articular head of the humerus is brought into contact with it by the next step—medial rotation. Owing to the continued traction the tendon of the subscapularis is tightly stretched over the head, which it presses through the gap when the traction is lessened. In this method an assistant steadies the patient's chest and scapula throughout, thus exerting counter-extension.

Kocher's Method of Reduction.—In the first instance the patient's elbow is pressed firmly against his side in order to fix the distal end of the humerus, as only by this means can subsequent manipulations exert their full action on the head of the bone. Grasping the patient's wrist with his free hand, the surgeon uses the forearm as a lever to produce lateral rotation of the humerus. This is effected by carrying the forearm away from the body till it is nearly in the frontal (coronal) plane, and the movement is performed slowly and steadily in order to overcome the muscular spasm. In this way the anatomical neck is disengaged from the glenoid margin, and the posterior aspect of the greater tubercle comes into contact with the articular surface of the glenoid cavity, from which it is separated by a part of the capsule.

The articular head now looks directly forwards, and if the tear has spread to the anterior aspect of the capsule, the tendon of the subscapularis, rendered tense by the excessive lateral rotation, may press the bone back into place.

If reduction does not occur at this stage, the elbow is carried forwards and medially, lateral rotation of the humerus being maintained through the position of the forearm. This movement of flexion and adduction stretches the capsule by tilting the greater tubercle backwards, and at this stage the head often passes back into place. Should it not do so, the patient's forearm is rapidly swung over towards the opposite shoulder to produce medial rotation of the humerus. If the elbow is elevated slightly during this movement, the head of the humerus descends, as it rotates medially, and passes through the torn inferior part of the capsule.

In testing passive movements or the limitations of movements following injury in the region of the right shoulder-joint, the surgeon stands behind the patient and holds the semi-flexed elbow of the affected side in his own right palm. This enables him to move the humerus at the shoulder-joint in any way he desires, while the left hand examines the injured region. The left shoulder is examined with the position of the hands reversed.

Complications.—Dislocation of the shoulder may be complicated by the tearing off of a part of the greater tubercle. If the fragment includes the insertion of the supra-spinatus, it is drawn upwards and subsequently limits abduction by becoming jammed beneath the acromion.

Fracture through the anatomical or surgical neck is a rare but important complication. The head of the humerus can be palpated through the superficial infra-clavicular triangle or beneath the coracoid process; but the diagnosis of the fracture will be determined if movement of the humeral shaft produces no effect on the head. Owing to the small size of the proximal fragment manipulative methods of reduction rarely succeed, and operative measures usually have to be adopted, the joint being approached from in front (p. 19).

Injuries to the brachial nerves following dislocation of the shoulder are described on p. 20 and pp. 99-108.

Attempts to reduce old-standing dislocations of the shoulder may cause rupture of the axillary artery and stretching or laceration of the brachial plexus, owing to the presence of adhesions between the head of the humerus and the axillary sheath. In these cases the lateral rotation carried out in Kocher's method of reduction exerts a powerful twisting or spiral strain upon the bone and, if the adhesions are strong, the humerus may be fractured spirally at the surgical neck. In the old-fashioned method of reduction by means of the heel in the axilla, the extending force is exerted along the long axis of the shaft of the humerus, and there is therefore no danger of spiral fracture. On the other hand, the upper ribs may be fractured, unless the pressure of the heel is directed towards the coracoid process and not against the chest wall.

Congenital Elevation of the Shoulder.—At an early period of development the scapula and clavicle occupy positions much nearer the head end of the embryo than they do at birth, and as the scapula grows in size it migrates caudally. Incomplete caudal migration of the scapula accounts for the condition of congenital elevation of the shoulder described by Eulenburg and Sprengel. It may be due to the presence of a bridge of bone joining the upper part of the vertebral border of the scapula to the lower cervical spines. This bridge of bone, which may possess a false joint at either end, is probably homologous with the cartilaginous supra-scapula found in some reptiles.

The upper border and medial (superior) angle of the scapula lie considerably above the head of the first rib, and may be mistaken for an exostosis. The muscles which elevate the scapula are all definitely shortened, and the skin is drawn up into a fold, which extends from the mastoid process to the acromion. The condition may be bilateral and is associated with cervical ribs, or with faulty ossification of the cervical vertebræ, which may be fused together leading to restriction of movement.

Position of the Scapula.—Under normal conditions the two scapulæ lie symmetrically on the dorsi-lateral aspect of the thoracic wall. This position is maintained by the 'balance' of the muscles which are capable of acting on it, chiefly, trapezius, serratus anterior, levator scapulæ, the rhomboids and pectoralis minor. When any one of these muscles is paralysed the 'balance' is upset, and the scapula on the affected side takes up a new position. In paralysis of the trapezius, the scapula drops to a lower level, the inferior angle is rotated backwards, and the vertebral border, as a whole, is farther from the median plane.

In paralysis of the trapezius the point of the shoulder drops to a lower level but, contradictory as it may appear at first sight, the inferior angle of the scapula is elevated on the affected side. The depression of the shoulder is attributable, primarily, to the weight of the limb, but the coraco-clavicular ligament anchors the scapula to the clavicle—itself anchored by its relations to the sternum and the first rib—and the degree of downward movement of the acromial end of the clavicle is sharply limited. The effect of the weight of the limb now accentuates the backward rotation of the scapula produced by the levator scapulæ and the rhomboids, which are only opposed by the serratus anterior. As a result of the amount of backward rotation of the scapula, its inferior angle is elevated to a higher level than normal. In addition the vertebral border is farther from the median plane.

In paralysis of the serratus anterior, the scapula is slightly raised on the affected side and it is rotated backwards, but the vertebral border is approximated to the median plane.

THE BREAST AND AXILLA

Development of the Mammary Gland.—The connective tissue of the mamma is mesodermal in origin, while the glandular tissue which infiltrates it is derived from the ectoderm. During the second month of embryonic life a distinct thickening of the ectoderm forms the *mammary ridge*, which extends from the axilla to the groin. Normally the thickening is limited to that part of the ridge which subsequently overlies the thorax, but occasionally it is not so limited, and then supernumerary nipples or breasts may appear.

During the third month the ectodermal nodule becomes depressed or invaginated into the underlying connective tissue so that a small pit is formed. In the fifth month solid ectodermal buds, from fifteen to twenty in number, grow inwards, and their stalks subsequently give rise to the epithelial lining of the lactiferous ducts. Extensive changes occur during the seventh and the ninth months. The lobes derived from the ectodermal buds subdivide to form lobules, which, at their growing ends, invade the surrounding connective tissue and fat, thus breaking up the mesodermal stroma into the interlobular septa and fibrous framework of the corpus mammæ. At the same time the whole ectodermal mass becomes canaliculised and gives rise to a system of ducts and alveoli, while the depressed area becomes evaginated on the surface to form the nipple. During the latter part of fœtal life the ampullæ develop in the lactiferous ducts, which open on the apex of the nipple.

At puberty, the size of the gland increases, owing to an increase in the parenchyma; *during pregnancy*, the glandular tissue proliferates, and the mamma reaches its full development; *at the menopause*, involution occurs in the more recently developed portions.

The **Mammary Gland** possesses no capsule; it consists of a central portion and of peripheral branching processes which radiate into the surrounding paramammary fat (Stiles). The superficial fascia, which covers it, sends down fibrous processes, called *the ligaments of Cooper*, to join the connective tissue septa which ramify throughout the gland. Prolongations of the parenchyma of the gland are found in the ligaments of Cooper, in the loose retro-mammary tissue, and sometimes even in the intervals between the fasciculi of the pectoralis major. When the ligaments of Cooper are invaded by malignant disease, they become shorter and cause dimpling of the skin, which, on this account, is no longer freely movable over the breast.

The breast rests upon the pectoral fascia and extends from the second rib above to the sixth costal cartilage below. At the level of the fourth rib it extends horizontally from the lateral border of the sternum to the fifth rib in the mid-axillary line (Stiles). Its medial half rests, above, upon the pectoralis major, and, below, on the aponeurosis of the external oblique where it covers the upper part of the rectus abdominis. Its lateral half lies upon the pectoralis major above, and on the serratus anterior (s. magnus) and the external oblique (digitations of origin) below. *Spence's axillary tail* is a narrow portion of the gland, which reaches up under cover of the pectoralis major as far as the third rib.

The **arterial supply** of the mammary gland is derived from the lateral (long) thoracic (p. 31) and the anterior perforating branches—especially the second and third—which arise from the internal mammary in the intercostal spaces and pass forwards through the pectoralis major near the margin of the sternum.

The **Lymph Vessels** of the breast may be divided into two sets—(1) the cutaneous, (2) the glandular.

(1) The *cutaneous lymph vessels* form a plexus beneath the areola, and from it the vessels extend, in the fibrous septa of the subcutaneous fat, towards the periphery of the breast, where they join the extensive lymphatic plexus in the fascia enveloping the pectoralis major—the pectoral plexus. (2) The *glandular lymph vessels*, which surround the alveoli, lie in the intra-lobular connective tissue and communicate in front with the cutaneous plexus and behind with the pectoral plexus.

It is necessary to detail the various connections of the pectoral plexus in order that the spread of malignant disease, both by centrifugal permeation and by embolic processes, may be understood. They can be conveniently tabulated.

Connections of Pectoral Plexus.

1. With subscapular lymph glands (p. 36), which drain the lateral part of the plexus.
2. With pectoral lymph glands (p. 35), which drain the upper and lateral part of the plexus.
3. With infra-clavicular lymph glands (p. 30), which drain the upper part of the plexus.
4. With the lymph glands which lie along the internal mammary vessels in the upper intercostal spaces, and through them, with the anterior mediastinal lymph glands, which thus drain the medial part of the plexus.
5. With the pectoral and cutaneous plexus of the opposite side, across the front of the sternum.
6. With the sub-peritoneal plexus on the under surface of the diaphragm, by communications which cross the costal margin, draining the lower part of the plexus.
7. With the central lymph glands of the axilla (Sampson-Handley).

Mammary Abscess.—Superficial abscess formation (*pre-mammary abscess*) is caused by organismal infection of the cutaneous lymph vessels or of the glands which form Montgomery's tubercles.

If the glandular lymph vessels become involved by a spreading infection, the abscess forms in the substance of the breast (*intra-mammary abscess*). In this case the abscess ramifies throughout the mamma, giving rise to loculi, which may be traversed by fibrous septa.

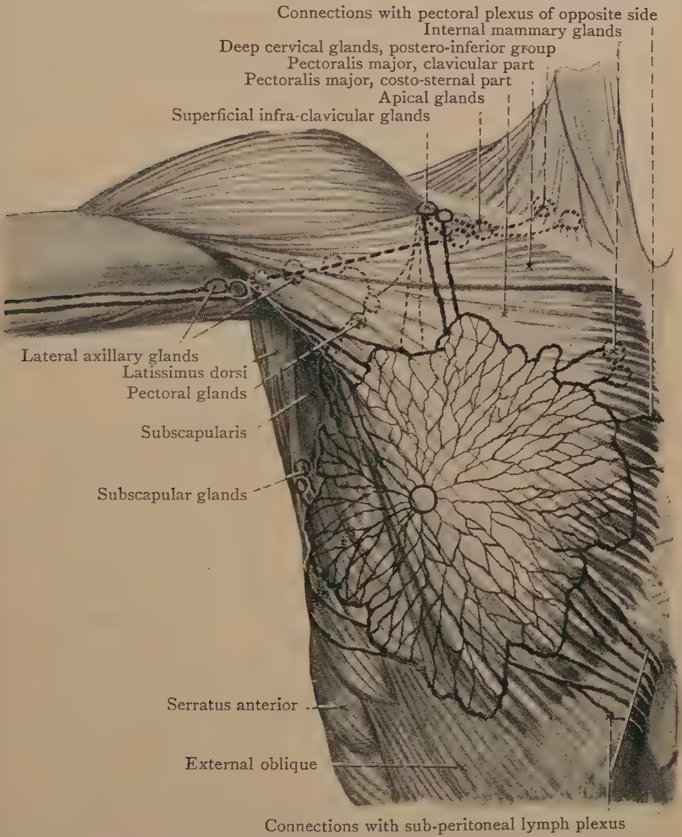

Connections with pectoral plexus of opposite side
Internal mammary glands
Deep cervical glands, postero-inferior group
Pectoralis major, clavicular part
Pectoralis major, costo-sternal part
Apical glands
Superficial infra-clavicular glands
Lateral axillary glands
Latissimus dorsi
Pectoral glands
Subscapularis
Subscapular glands
Serratus anterior
External oblique
Connections with sub-peritoneal lymph plexus

FIG. 8.—The Connections of the Pectoral Lymphatic Plexus. The lymph vessels and glands which lie deep to the muscles are indicated by the dotted lines and circles.

When the infection passes to the pectoral plexus, it gives rise to an abscess behind the breast (*retro-mammary abscess*). This variety more commonly arises from a deeper cause, such as empyæma, tuberculous disease of a rib, etc., and it tends to push the breast and the pectoralis major forwards; after perforating the latter, the abscess may point in the areola or gravitate towards the infra-mammary groove.

Incisions for the pre- and intra-mammary abscesses radiate from the nipple, in order to avoid injuring the lactiferous ducts. If the retro-mammary abscess is caused by a forward spread from deeper structures, the breast may be turned upwards by a long curved incision in the infra-mammary groove. In this way good access is obtained and no important structures are injured. The same approach serves for removal of the breast in chronic mastitis and other simple conditions.

THE AXILLA.—The axilla is the space between the upper part of the chest wall and the proximal part of the upper limb. In shape it resembles a pyramid with a blunted apex, through which the great vessels and nerves pass from the root of the neck to the axilla. The apex is bounded, in front, by the middle third of the clavicle; behind, by the upper border of the scapula; and medially, by the outer border of the first rib.

Axillary Fascia.—The hollowed-out base of the pyramid, *i.e.* the floor of the axilla, is formed by the axillary fascia, which is an extremely strong sheet. It is continuous in front with the fascial envelope of the pectoralis major, and behind with that of the latissimus dorsi. Below, and medially, it blends with the fascia covering the serratus anterior (magnus), and it is continuous laterally with the deep fascia of the arm. Owing to the great strength of the axillary fascia, abscesses rarely rupture through it spontaneously.

The Anterior Wall of the Axilla consists of two strata. The pectoralis major and its fascia form the superficial, and the pectoralis minor and the clavi-pectoral fascia form the deep layer.

The **Pectoral Fascia** closely envelops the pectoralis major. Above, it is attached to the clavicle, and, in its lateral part, it forms the roof of the superficial infra-clavicular triangle. Medially, it is attached to the sternum, and below it is continuous with the fascial covering of the external oblique and the serratus anterior. Laterally, it blends with the axillary fascia below and with the fascia of the arm above.

The pectoral fascia contains the efferent mammary lymph vessels, and hence the necessity for its exposure and removal in cancer of the breast. The best access to the fascia is obtained by an incision extending from the insertion of the pectoralis major to the tip of the eighth costal cartilage of the opposite side (Stiles). This incision divides so as to enclose the tumour and an equally wide area of skin and cutaneous lymph vessels all round it.

To expose the fascia completely, the skin above the incision is dissected upwards and medially until the clavicle and the opposite margin of the sternum are visible ; the skin below the incision is undercut backwards until the level of the posterior wall of the axilla is reached, and downwards until the sheath of the rectus abdominis and the upper digitations of the external oblique are well exposed.

The **Pectoralis Major** arises by a *Clavicular Head* from the front of the medial third or more of the clavicle and by a *Costo-sternal Head* from the front of the sternum, from the aponeurosis of the external oblique, and from the upper five or six costal cartilages. These two heads of origin remain quite distinct from one another almost to the insertion into the lateral lip of the inter-tubercular sulcus (bicipital groove). The pectoralis major is a powerful adductor, and it helps in medial rotation of the humerus. The clavicular head, aided by the coraco-brachialis and the anterior fibres of the deltoid, flexes the humerus, a movement which carries the limb forwards and medially. The costo-sternal head acts as an extensor of the flexed humerus and as a flexor of the extended humerus. The muscle is supplied by the lateral and medial anterior thoracic nerves (C. 5, 6, and 7, C. 8 and T. 1).

If the clavicular head is preserved in the operation of complete excision of the breast, no movements are lost, although the arm is weakened by the removal of the costo-sternal portion.

The *deep stratum of the anterior wall of the axilla* is formed by the clavi-pectoral fascia, the pectoralis minor, and the subclavius.

The **Pectoralis Minor** arises from the bony sternal extremities of the third, fourth, and fifth ribs, under cover of the pectoralis major, and runs upwards and laterally to be inserted into the medial border of the coracoid process. It is supplied by the medial anterior thoracic nerve (C. 8 and T. 1), from the medial cord of the brachial plexus. The nerve pierces the muscle about 1½ inches from its insertion and enters the pectoralis major. The pectoralis minor helps in forward and downward movements of the shoulder girdle ; and, when the scapula is fixed, it acts as an elevator of the ribs.

The **Subclavius**, which lies between the clavicle and the first rib, is supplied by a small nerve which is formed by twigs from C. 5 and C. 6. It helps to steady the clavicle in movements of the shoulder, by pulling it medially towards the sternum.

The **Clavi-Pectoral Fascia** extends from the clavicle above to the axillary fascia below. It forms the fascial sheath of the subclavius, and is attached to the edges of the groove for that muscle on the clavicle. The layers enclosing the subclavius fuse at its lower border to form the costo-coracoid membrane, which fills in the gap in the deep stratum of the anterior axillary wall between the subclavius above and the pectoralis minor below (Fig. 9).

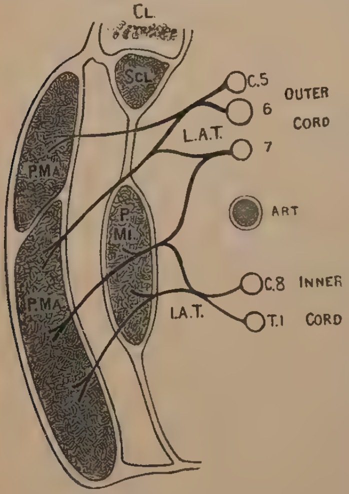


FIG. 9.—Diagram of a Section through the Anterior Wall of the Axilla.

L.A.T.	Lateral anterior thoracic nerve.
I.A.T.	Medial anterior thoracic nerve.
ART.	Axillary artery, second part.
P.MA.	Pectoralis major muscle.
P.MI.	Pectoralis minor muscle, connected by costo-coracoid membrane with
SCL.	Subclavius muscle.
CL.	Clavicle.

The **Costo-Coracoid Membrane** is attached medially to the first costal cartilage, laterally to the coracoid process, while, below, it splits to enclose the pectoralis minor. At its medial end, it lies behind the clavicular head of the pectoralis major; at its lateral end, it constitutes the floor of the superficial infra-clavicular triangle. The infra-clavicular lymph glands lie on its anterior surface, and it is pierced by the cephalic vein (p. 50), the thoraco-acromial (thoracic axis) artery and vein, and the lateral anterior thoracic nerve. The axillary sheath lies behind the membrane, separated from it by the loose fat and the apical lymph glands of the axilla. It is here that the surgeon ligatures the first part of the axillary artery, taking the thoraco-acromial artery as his guide.

At the lower border of the costo-coracoid membrane the clavi-pectoral fascia splits to enclose the pectoralis minor, and the layer on the anterior surface of the muscle is intimately connected to the fascia on the deep surface of the pectoralis major. Below the pectoralis minor the two layers of the clavi-pectoral fascia fuse to form a single sheet, which passes down to join the axillary fascia and is termed the *suspensory ligament* *of the axilla.* This layer of fascia is attached laterally to the deep fascia of the arm, in front of the great vessels and nerves.

The **Thoraco-Acromial (Thoracic Axis) Artery** arises from the second part of the axillary artery, pierces the medial part of the costo-coracoid membrane, close to the upper border of the pectoralis minor and breaks up into *deltoid* (p. 35), *acromial, clavicular* (p. 9), and *pectoral branches.* The pectoral branches pass downwards in the interval between the two pectoral muscles, accompanied by branches of the lateral anterior thoracic nerve. In excision of the breast, hæmorrhage may be reduced by securing these branches prior to removal of the sternal portion of the pectoralis major. They may be hooked up on the forefinger through the interval between the clavicular and sternal portions of the pectoralis major (p. 3), as they wind round the upper border of the pectoralis minor (Stiles).

The **Lateral (Long) Thoracic Artery** passes from the second part of the axillary artery downwards and medially, along the lower border of the pectoralis minor, to the fifth intercostal space. Its *External Mammary branch* reaches the mamma by passing medially over the pectoralis major.

The pectoral and infra-clavicular lymph glands, with their efferent lymph vessels from the upper and lateral parts of the pectoral plexus, are so intimately connected with the pectoral fascia of the anterior axillary wall that this wall is usually removed in malignant disease of the breast. The costo-sternal portion of the pectoralis major is divided near its insertion and is then reflected from its origin. As the cut muscle is drawn forwards and laterally, the fascia covering the serratus anterior and the external oblique is rendered tense, and may be removed as a wide sheet as far back as the subscapularis. It is at this stage of the operation that the long thoracic nerve (of Bell) is in danger, as it runs down the medial wall of the axilla between the serratus anterior and its covering fascia.

The Medial Wall of the Axilla is formed by the upper five ribs and external intercostal muscles, partially covered by the upper digitations of the serratus anterior.

The **Serratus Anterior (S. magnus)** arises from the lateral surfaces of the upper eight ribs, a short distance in front of the mid-axillary line. Its fibres pass backwards, closely applied to the chest wall, and are inserted into the ventral aspect of the vertebral border of the scapula. It receives its nerve-supply from the long thoracic nerve (of Bell) (C. 5, 6, 7) (pp. 99, 135). The serratus anterior pulls the scapula forwards, and, when opposed by the rhomboids, it steadies the scapula in the movements of forward pushing. In addition, by rotating the scapula it enables the arm to be raised above the head and is helped by the trapezius in producing this movement. When the scapula is fixed by the trapezius and the rhomboids, it acts as an elevator of the ribs.

The *lateral cutaneous branches* of the *second* and *third intercostal nerves* pierce the medial wall and run laterally across the axilla. They supply the skin over the floor of the axilla and the medial aspect of the arm; the uppermost is termed the *intercosto-brachial* (*intercosto-humeral*) *nerve*, and it communicates with the medial cutaneous nerve of the arm (lesser internal cutaneous). In malignant disease of the breast intermittent pain may be referred to the medial side of the arm, in the area supplied by these two nerves. It is suggested that this is due to pressure on the intercosto-brachial nerve by enlarged axillary lymph glands; but the pain is very frequently referred from the irritated sympathetic branches supplying the mammary gland itself.

The Lateral Wall of the Axilla, to which the important vessels and nerves are closely related, is narrow and is formed by the biceps, the coraco-brachialis, and the proximal part of the humeral shaft.

The **Axillary Sheath** is a prolongation of the prevertebral fascia (p. 113) from the neck. It encloses the vessels and nerves (and some of the apical lymph glands), and gradually becomes lost upon them as they pass through the axilla. In malignant disease of the breast, the apical lymph glands are removed, and they may be exposed by resecting a part of the sheath and separating the artery from the vein.

Axillary Artery.—The course of the axillary artery may be mapped out on the surface by drawing a line from the middle of the clavicle to the medial side of the elevation formed by the coraco-brachialis (p. 38), the limb being abducted to a right angle. The vessel is about six inches long and extends from the outer border of the first rib to the lower border of the teres major. It is conveniently divided into three parts by the pectoralis minor. The *First* Part lies above the muscle; the *Second*, behind the muscle; the *Third*, below the muscle.

The **First Part of the axillary artery** lies behind the costo-coracoid membrane and the clavicular head of the pectoralis major, and it is crossed by the cephalic and thoraco-acromial veins. Posteriorly, the artery rests on the first intercostal space and the first digitation of the serratus anterior, but it is separated from them by the long thoracic nerve (of Bell), and, usually, by the medial cord of the brachial plexus. To the lateral side are the lateral and posterior cords of the brachial plexus; to the medial side, and overlapping the artery anteriorly, is the axillary vein.

Ligature of this part of the artery has been referred to already (p. 30). The *collateral circulation* is carried on by the scapular anastomosis, where the transverse scapular (suprascapular) (p. 14) and the descending branch of the transverse cervical, from the subclavian (p. 12), meet the subscapular and circumflex scapular (dorsalis scapulæ) branches from the axillary. Further, branches from the intercostals anastomose on the chest wall with the lateral (long) thoracic and subscapular arteries and with the pectoral branches of the thoraco-acromial.

The *superior thoracic* is the only branch of the first part of the axillary artery. It crosses the apex of the axilla to supply the lymph glands and other structures in the first intercostal space.

The **Second Part of the axillary artery** has the lateral cord of the brachial plexus to its lateral side, the posterior cord behind it, and the medial cord and the medial anterior thoracic nerve, which separate the artery from the axillary vein, to its medial side. Behind the artery and the posterior cord there is a pad of fat, which intervenes between them and the subscapularis muscle.

The *branches* of this part of the artery are the thoraco-acromial (p. 31) and the lateral thoracic (p. 31).

The **Third Part of the axillary artery** lies under cover of the pectoralis major above, but it is subcutaneous below. There are two nerves on each side of the artery. *Laterally,* lie the lateral head of the median and the musculo-cutaneous nerve, which deviates laterally to pierce the coraco-brachialis (Fig. 10). *Anteriorly,* lie the medial head of the median and the medial cutaneous nerve of the forearm (internal cutaneous nerve). *Medially,* the ulnar nerve separates the artery from the axillary vein, and the medial cutaneous nerve of the arm (lesser internal cutaneous nerve) is closely applied to the medial side of the vein. *Posteriorly* are the radial (musculo-spiral) and axillary (circumflex) nerves, but the latter leaves the artery at the lower border of the subscapularis by passing backwards into the quadrilateral space.

The Third Part of the axillary artery is superficial, and is the site of election for *Ligation*. The vessel may be tied immediately above the origin of the subscapular or between this vessel and the posterior circumflex. In the former case, the circulation is carried on by the anastomosis between the intercostals, lateral thoracic, descending branch of transverse cervical, transverse scapular (supra-scapular), and thoraco-acromial arteries, on the proximal side of the ligature, and the subscapular and humeral circumflex arteries, on the distal side of the ligature.

Collateral Circulation.—The circumflex arteries anastomose with the acromial branch of the thoraco-acromial and the transverse scapular (p. 18). The subscapular anastomoses with the descending branch of the transverse cervical and the transverse scapular arteries in the *scapular anastomosis*, and with the intercostals, the lateral thoracic and pectoral branches of the thoraco-acromial in the serratus anterior, near the inferior angle of the scapula.

When the axillary artery is tied between the subscapular and circumflex vessels, the anastomosis just referred to between the circumflex, the acromial branch of the thoraco-acromial and the transverse scapular arteries re-establishes the circulation.

When the subscapular and circumflex vessels arise by a common trunk and a ligature is applied distal to this vessel, the collateral anastomosis follows the same course as in ligature of the brachial artery proximal to the origin of the (superior) profunda (p. 43).

Branches of the Third Part of the Axillary Artery.—(1) The *subscapular* is the largest branch of the axillary artery. It arises near the lower border of the subscapularis, along which it descends accompanied by its companion vein and the thoraco-dorsal (long subscapular) nerve. A short distance from its origin it gives off the *circumflex scapular* (*dorsalis scapulæ*) *artery*, which winds round the axillary border of the scapula close to the bone to reach its dorsal surface (p. 33). (2) *The posterior circumflex* (p. 18). (3) *The anterior circumflex* (p. 18).

These three arteries occasionally arise by a common trunk, which leaves the third part of the axillary artery near its commencement.

Aneurism of the first part of the axillary artery pushes forwards the costo-coracoid membrane and tends to project below the clavicle in the superficial infra-clavicular triangle. Aneurism of the third part projects into the axilla and gives rise to a swelling or convexity of the floor of the axilla. Both varieties may press upon the axillary vein and obstruct the venous return, thus causing swelling and œdema of the upper limb

The **Axillary Vein** is formed at the lower border of the teres major by the basilic vein, and is soon joined by the venæ comites of the brachial artery. It ends at the outer border of the first rib, where it becomes continuous with the subclavian vein. As it passes through the axilla it lies to the medial side of the artery, but is separated from it by the ulnar nerve, below, and by the medial cord of the plexus, above. When the arm is abducted, the vein lies in front of the artery and hides it from view. Its principal tributaries are the cephalic and the subscapular veins. The latter possesses a wide anastomosis with the veins of the thoracic wall near the inferior angle of the scapula. The subscapular vein and the branches of the anastomosis are associated with the posterior group of lymph glands, and all these structures are removed, as a routine measure, in excision of the breast. After the thoraco-dorsal (long subscapular) nerve has been isolated, the subscapular vessels are tied close to the axillary artery and then stripped downwards. In the process the lower (middle) subscapular nerve is exposed, as it runs laterally, in front of the subscapularis and behind the vessels, to reach the teres major.

The LYMPH GLANDS of the axilla are arranged in four groups :

1. The **Pectoral lymph glands** lie in the medial part of the interval between the suspensory ligament of the axilla (p. 30) and the posterior surface of the pectoralis major. They drain not only the breast, but also the superficial layers of the anterior abdominal wall above the umbilicus.

An *abscess* arising from these glands cannot extend upwards into the neck as the two layers of fascia between which it lies are both attached to the clavicle (Fig. 9). This abscess tends to point either at the upper or lower border of the pectoralis major. Incisions should be made parallel to these borders to avoid injuring the deltoid branch of the thoraco-acromial artery (p. 31) in the one case, and the lateral thoracic artery (p. 31) in the other.

2. The **Lateral lymph glands** accompany the axillary vein and lie on the lateral wall of the axilla. They receive the efferents from the upper limb and are involved early in lymphangitis of the fingers and forearm.

An *abscess* arising from these glands lies in the axilla behind the clavi-pectoral fascia and produces a bulging of the axillary fascia. The pus cannot pass far backwards owing to the attachment of the serratus anterior to the scapula, but it may burrow through the intercostal spaces and infect the pleura, or it may pass upwards behind the axillary sheath (p. 32) and appear in the root of the neck. Rarely, the pus burrows through the subscapularis and infects the shoulder-joint.

This abscess should be opened through the axillary fascia by cutting in the direction of the medial wall and parallel to the long thoracic nerve (of Bell). In this way the lateral thoracic artery on the anterior wall, the subscapular vessels and thoraco-dorsal nerve on the posterior wall, and the great vessels and nerves on the lateral wall, are all avoided.

3. The **Subscapular group of lymph glands** lies on the subscapularis at the inferior angle of the scapula and is closely associated with the subscapular vessels and the thoraco-dorsal nerve. They receive efferents from the pectoral plexus and afferents from the superficial layers of the back corresponding to the thoracic part of the vertebral column.

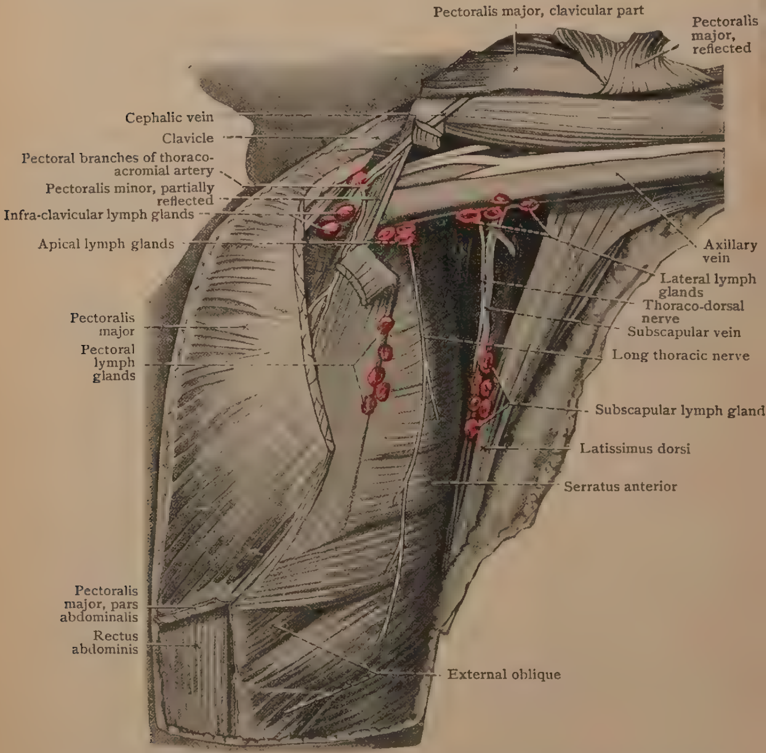

Pectoralis major, clavicular part
Pectoralis major, reflected
Cephalic vein
Clavicle
Pectoral branches of thoraco-acromial artery
Pectoralis minor, partially reflected
Infra-clavicular lymph glands
Apical lymph glands
Axillary vein
Lateral lymph glands
Thoraco-dorsal nerve
Subscapular vein
Long thoracic nerve
Pectoralis major
Pectoral lymph glands
Subscapular lymph gland
Latissimus dorsi
Serratus anterior
Pectoralis major, pars abdominalis
Rectus abdominis
External oblique

FIG. 10.—The Axilla and its Lymph Glands. A small part of the anterior wall of the rectus sheath has been removed, and the pectoralis minor has been partially divided.

Abscesses arising in connection with this group may spread in the same directions as in (2). They should be opened by an incision parallel to the axillary border of the scapula, so as to avoid injury to the subscapular vessels and nerve.

4. The **Apical lymph glands** are situated at the apex of the axilla and lie behind the costo-coracoid membrane. Some lie on the first intercostal space; others along the axillary sheath; while others are situated within the sheath in contact with the vein. They receive the efferents of the subscapular, pectoral, and lateral groups, and are connected, through the costo-coracoid membrane, with the infra-clavicular lymph glands in the superficial infra-clavicular triangle. The apical lymph glands may become adherent to the axillary vein in malignant disease and necessitate the excision of a part of that vessel; they may also press upon the cephalic vein as it pierces the costo-coracoid membrane in such a way as to render it prominent throughout its course in the arm. Efferents from this group open into the lymph glands at the root of the neck, and Halstead considers that these should be removed in the routine operation for scirrhus mammæ.

The Posterior Wall of the Axilla is formed by the subscapularis, teres major, and the tendon of the latissimus dorsi.

The *Subscapularis* arises from the venter of the scapula and passes upwards and laterally in front of the shoulder-joint to be inserted into the lesser tubercle of the humerus and the capsule of the joint. It helps in adduction and medial rotation of the arm and receives its nerve-supply from the upper (short) and lower (middle) subscapular nerves (C. 5 and 6).

The *Latissimus dorsi* (p. 273) is inserted into the floor of the intertubercular sulcus of the humerus. It is a powerful extensor of the flexed humerus and an equally powerful adductor of the abducted humerus, and, in addition, it helps in medial rotation. It is supplied by the thoraco-dorsal (long subscapular) nerve (C. 6, 7, and 8).

The *Teres major* arises from the dorsal aspect of the inferior angle of the scapula and runs upwards and laterally to be inserted into the medial lip of the intertubercular sulcus. Its action corresponds to that of the latissimus dorsi. It is supplied by the lower (middle) subscapular nerve (C. 5 and 6).

The great vessels and nerves of the axilla lie on the upper part of this wall, and the subscapular vessels (p. 34) and the three subscapular nerves, which all arise from the posterior cord, are closely related to it.

The Brachial Plexus and its important branches will be considered in detail in a subsequent section (p. 95), but the nerves must be identified as they surround the third part of the axillary artery. The **Median** is recognised by its two heads of origin and by its great size. The **Musculo-Cutaneous** is recognised by its lateral position and by its deviation to reach and pierce the coraco-brachialis. It is smaller than the median, but occasionally it includes a large part of the lateral head of the median, and the two nerves then tend to resemble one another and can be distinguished only by their relative positions. This part of the lateral head subsequently joins the median nerve in the arm.

Some difficulty may be experienced in distinguishing the **Ulnar** from the **Medial Cutaneous Nerve of the Forearm (Internal Cutaneous)**. They both arise from the medial cord and are hidden at their origin by the axillary vein. The medial cutaneous is the more anterior and the smaller of the two.

The **Radial (Musculo-spiral)** is the direct continuation of the posterior cord and consequently lies behind the artery. It can be distinguished from the ulnar by its greater size and by its position.

REGION OF (UPPER) ARM.

Muscular Landmarks.—The elevation produced by the *biceps* on the front of the arm is limited by the lateral and medial bicipital furrows. In its proximal part the medial furrow is obscured by the *coraco-brachialis*, which is seen best when resistance is offered to adduction of the abducted arm.

When the elbow is forcibly extended against resistance, the *lateral head of the triceps* gives rise to a distinct prominence, which lies below and parallel to the posterior border of the deltoid. The *long head of the triceps* can be seen, as it emerges from under cover of the proximal part of the posterior border of the deltoid, when the abducted arm is viewed from behind. The muscular mass on the medial aspect of the back of the arm is produced by the large *medial head of the triceps*.

The **Deep Fascia of the Arm** receives attachments to the humeral epicondyles and the subcutaneous border of the olecranon in the elbow region. The *Medial and Lateral Intermuscular Septa* are processes of fascia which extend from the ensheathing layer to the epicondylic ridges and shaft of the humerus. The medial septum extends from the medial epicondyle to the insertion of the coraco-brachialis, the lateral from the lateral epicondyle to the insertion of the deltoid. These septa, together with the humerus, divide the arm into an anterior and a posterior compartment, and, to a certain extent, limit the course of pus or hæmorrhagic extravasation.

The **Triceps Brachii** occupies the whole of the posterior compartment of the arm, and is inserted into the proximal surface of the olecranon. It is a powerful extensor of the elbow, and it is supplied by the radial (musculo-spiral) nerve (C. 7 and 8).

The **Axillary (Circumflex) Nerve** (p. 33) winds horizontally round the surgical neck of the humerus in the quadrilateral space, where it is in close relation to the dependent part of the capsule of the shoulder-joint (p. 16). In this region it may be injured by the pressure of a crutch, by the head of the humerus in sub-glenoid dislocations, and by the fragments in fracture of the surgical neck. The nerve supplies the teres minor and the deltoid. It can be mapped out on the surface by a horizontal line, which intersects the line drawn from the lateral border of the acromion to the insertion of the deltoid, at the junction of its proximal and middle thirds. The results of injury to the axillary nerve are described on page 103.

Surgical Approach to the Proximal Part of the Humerus.—In disease or injury of the **Proximal Part of the Shaft** (or diaphysis) of the humerus, the best approach is obtained by a long incision, parallel to the posterior border of the deltoid (Stiles). When the muscle is undermined and retracted, the quadrilateral space is exposed, and the large cutaneous branch of the axillary nerve is seen passing forwards round the edge of the deltoid. The *quadrilateral space* is bounded above by the teres minor, below by the teres major, laterally by the surgical neck of the humerus, and medially by the long head of the triceps. Through it the axillary nerve and the posterior circumflex vessels pass backwards in close relation to the surgical neck of the humerus and the dependent part of the capsule of the shoulder-joint. Anterior to the origin of the lateral head of the triceps and above the insertion of the deltoid, the humerus is uncovered by muscles and offers good access to the surgeon.

The proximal part of the diaphysis of the humerus may be resected subperiosteally for tuberculous osteomyelitis. After the periosteum has been elevated, the diaphysis need only be divided distal to the disease, as the part to be resected may then be wrenched out from its periosteal sheath. In this way the epiphyseal cartilage is left attached to the epiphysis and the joint cavity is not opened (Fig. 6).

Below the teres major the **Radial (musculo-spiral) nerve** lies on the long head of the triceps, and after supplying this muscle, it enters the radial groove in company with the (superior) profunda branch of the brachial artery. In the groove it supplies the medial and lateral heads of the triceps between which it

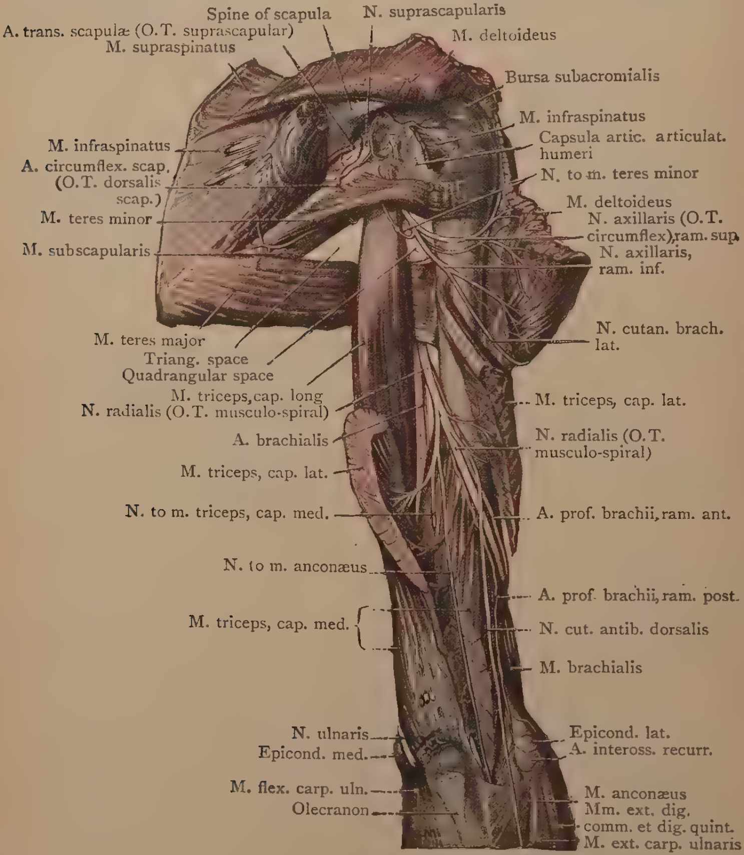

Spine of scapula
N. suprascapularis
A. trans. scapulæ (O.T. suprascapular)
M. supraspinatus
M. deltoideus
Bursa subacromialis
M. infraspinatus
Capsula artic. articulat. humeri
M. infraspinatus
A. circumflex. scap. (O.T. dorsalis scap.)
N. to m. teres minor
M. deltoideus
M. teres minor
N. axillaris (O.T. circumflex), ram. sup.
M. subscapularis
N. axillaris, ram. inf.
N. cutan. brach. lat.
M. teres major
Triang. space
Quadrangular space
M. triceps, cap. long
N. radialis (O.T. musculo-spiral)
M. triceps, cap. lat.
A. brachialis
N. radialis (O.T. musculo-spiral)
M. triceps, cap. lat.
N. to m. triceps, cap. med.
A. prof. brachii, ram. ant.
N. to m. anconæus
A. prof. brachii, ram. post.
M. triceps, cap. med.
N. cut. antib. dorsalis
M. brachialis
N. ulnaris
Epicond. med.
Epicond. lat.
A. inteross. recurr.
M. flex. carp. uln.
Olecranon
M. anconæus
Mm. ext. dig. comm. et dig. quint.
M. ext. carp. ulnaris

FIG. 11.—The Back of the Arm.

lies, and it passes distally and laterally across the back of the arm. At the distal end of the groove it pierces the lateral intermuscular septum and enters the anterior compartment of the arm. The point at which it pierces the septum may be indicated on the surface at the union of the proximal and middle thirds of the line joining the lateral epicondyle to the insertion of the deltoid. A line drawn across the back of the arm from the termination of the axillary artery to this point maps out the nerve as it lies in the radial groove.

In the anterior compartment the radial (musculo-spiral) nerve lies on the lateral border of the brachialis (b. anticus), and is covered in front by the brachio-radialis (supinator longus) proximally and the extensor carpi radialis longus distally. It ends in front of the lateral epicondyle of the humerus by dividing into *superficial* (*radial*) and *deep* (*posterior interosseous*) *branches*.

Callus following a fracture of the shaft of the humerus sometimes implicates the radial (musculo-spiral) nerve, necessitating operative interference. The nerve can be conveniently found as it pierces the lateral intermuscular septum, and it can then be traced upwards by cutting through the musculo-tendinous roof of the radial groove, until the damaged portion is found. In the usual procedure the nerve is sought for in the anterior compartment by separating the brachio-radialis from the brachialis (b. anticus). Owing to the absence of a well-marked septum, the groove between these muscles, which are closely applied to one another, is not easy to determine. The interval between the brachialis and the biceps may inadvertently be opened, in which case the musculo-cutaneous nerve is exposed (*vide infra*). Injury to the radial (musculo-spiral) nerve is dealt with on p. 103.

Muscles of the anterior compartment.—The *coraco-brachialis* is inserted into the middle of the shaft of the humerus on the medial side, and helps in flexion and adduction of the arm. Its nerve-supply from the musculo-cutaneous nerve is derived entirely from C. 7.

The *biceps brachii* arises by a long head (p. 18) and by a short head from the tip of the coracoid process. It is inserted into the posterior part of the tuberosity of the radius and is separated from the anterior part by a bursa. Primarily, it is a flexor and supinator of the forearm; secondarily, it helps to produce flexion and adduction at the shoulder. The musculo-cutaneous nerve (C. 5 and 6) supplies both heads.

The biceps occupies the greater part of the anterior compartment of the arm, and its medial border is the surgical guide to the brachial artery. The belly or either head of the muscle may be ruptured during violent movements, and, as a result, flexion of the elbow and forcible supination are much weakened.

The *brachialis* (*b. anticus*) covers the distal half of the anterior surface of the humerus and passes in front of the anterior ligament of the elbow to be inserted into the front of the coronoid process of the ulna. It is a powerful flexor of the elbow, and it derives its nerve-supply from the musculo-cutaneous (C. 5 and 6) and the radial (musculo-spiral) nerves (C. 5 and 6).

In fracture of the distal part of the shaft of the humerus a portion of the brachialis may become interposed between the two fragments causing non-union.

The shaft of the humerus should be examined along the lines of the intermuscular septa (p. 38), as the anterior and posterior surfaces of the bone are obscured by muscles. At its distal end, however, it may be examined by deep pressure through the brachialis in front and the triceps behind, provided that the muscles are relaxed by supporting the elbow.

Fractures of the Humerus.—Some reference must be made to the common sites of fracture of the humeral shaft on account of the displacement of the fragments. Although the displacements may be due primarily to the direction of the force causing the fracture, ultimately they are due to the action of the muscles attached to the fragments.

Fractures may occur:

1. **Through the Anatomical Neck** (p. 23).
2. **Through the Surgical Neck.**—The proximal fragment is slightly abducted by the supra-spinatus, but is not rotated, as the lateral rotators attached to the greater tubercle are opposed by the subscapularis on the lesser tubercle. The distal fragment is drawn proximally by the triceps, the biceps, and the deltoid, and medially by the muscles inserted into the intertubercular sulcus (bicipital groove).
3. **Immediately Proximal to the Insertion of the Deltoid.**—The proximal fragment is adducted by the latissimus dorsi, the pectoralis major, and the teres major. The distal fragment is drawn proximally by the deltoid, the triceps, and the biceps.
4. **Distal to the Insertion of the Deltoid.**—The proximal fragment tends to be abducted by the deltoid. The distal fragment is drawn proximally and somewhat medially by the biceps and the triceps, which act through the elbow-joint.
5. **Proximal to the Epicondyles** (p. 63).—The distal fragment is usually drawn proximally behind the proximal fragment by the biceps and the triceps. The distal end of the proximal fragment may perforate the brachialis and injure the brachial artery.

The **Musculo-cutaneous** nerve, on leaving the axillary artery (p. 33), supplies the coraco-brachialis and then pierces it. It runs distally between the biceps in front and the brachialis behind, supplying both muscles, and emerges at the elbow at the lateral side of the tendon of the biceps (p. 47). The results of injury to this nerve are detailed on p. 104.

The **Brachial Artery** is the direct continuation of the axillary. It begins at the lower border of the teres major and ends in the cubital fossa (p. 45), half an inch distal to the mid-point of the line joining the two epicondyles, where it divides into the radial and ulnar arteries.

In its **proximal third** the artery lies to the medial side of the humerus and can be compressed laterally against the bone. In *ligature* of this part the artery is found immediately under the deep fascia, but it is overlapped laterally by the coraco-brachialis, from which it is partially separated by the median nerve. Both the medial cutaneous nerve of the forearm (internal cutaneous) and the ulnar nerve (p. 38) lie to its medial side and separate it from the basilic vein. Behind the artery lie the long head of the triceps and the radial (musculo-spiral) nerve.

The **middle third of the brachial artery** can be compressed backwards and laterally against the bone. In *ligation* of this part the artery is found to be overlapped by the medial border of the biceps, and to be covered by the median nerve, which crosses it very obliquely about the middle of the arm. The ulnar nerve lies to its medial side, but is diverging from the artery to reach the medial intermuscular septum. Posteriorly, it lies on the insertion of the coraco-brachialis and on the brachialis. The medial cutaneous nerve of the forearm (internal cutaneous) and the basilic vein are both separated from the vessel by the deep fascia, which they pierce at the middle of the arm.

The **distal third of the artery** lies in front of the distal part of the humerus and can be compressed backwards against it. In *ligature* of this part, the artery is found to be overlapped by the medial border of the biceps, but near its termination it lies to the medial side of the tendon of that muscle and is crossed anteriorly by the lacertus fibrosus (bicipital fascia) (p. 45). The median nerve lies to its medial side.

Branches.—(1) The (*Superior*) *Profunda* arises near the commencement of the brachial artery and runs with the radial (musculo-spiral) nerve.

(2) The *Superior Ulnar Collateral* (*Inferior Profunda*) usually arises near the middle of the arm (p. 44).

(3) The *Inferior Ulnar Collateral* (*Anastomotica Magna*) (p. 44).

(4) The *Nutrient artery* usually arises from a muscular branch to the brachialis; it may be injured in fractures of the humerus, and, in these cases, it is said that delayed union results.

Collateral Anastomosis—(*a*) *Ligature Proximal to the Origin of the Profunda Artery.*—The circulation is re-established through an anastomosis which occurs between a descending branch from the posterior circumflex (p. 18) and an ascending branch from the profunda.

(*b*) *Ligature between the Origins of the Profunda and the Superior Ulnar Collateral* (*Inferior Profunda*).—The profunda artery divides into anterior and posterior branches at the distal end of the radial (musculo-spiral) groove. The anterior branch accompanies the radial (musculo-spiral) nerve into the groove between the brachio-radialis and the brachialis to anastomose with the radial recurrent, which enters the same groove at its distal end. The posterior branch runs distally behind the lateral intermuscular septum and anastomoses behind the lateral epicondyle with the dorsal interosseous recurrent (p. 71), which ascends under cover of the anconæus, upon the supinator (s. brevis) and the annular (orbicular) ligament. It is also joined by a transverse branch from the inferior ulnar collateral (anastomotic) artery.

(*c*) *Ligature between the Origins of the Superior and Inferior Ulnar Collateral Arteries* (*Inferior Profunda and Anastomotic*).—The Superior Ulnar Collateral accompanies the ulnar nerve (p. 43). The Inferior Ulnar Collateral arises two inches proximal to the bend of the elbow and runs medially upon the brachialis, passing behind the median nerve. It gives off an anterior branch, which runs distally in the groove between the brachialis and the pronator teres to anastomose with the anterior ulnar recurrent. The artery then pierces the medial intermuscular septum and joins the superior ulnar collateral to anastomose, behind the medial epicondyle, with the posterior ulnar recurrent.

The anastomosis detailed in (*b*) will also help to re-establish the circulation.

(*d*) *Ligature just above the Termination of the Brachial Artery.*—The collateral circulation is the same as that described in (*c*).

The **Medial Supracondylar Triangle** is bounded laterally by the brachial artery and medially by the medial intermuscular septum. Its base is formed by the medial part of the intercondylar line. The triangle contains the median nerve and the *epitrochlear lymph gland*, the former behind the deep fascia, and the latter superficial to it. This gland is very often the seat of lymphadenitis and abscess formation, secondary to septic infection of the fingers or forearm. In excision of the gland the volar branch of the medial cutaneous nerve of the forearm (internal cutaneous nerve) may be injured (p. 48).

THE REGION OF THE ELBOW.

Bony Landmarks.—Both *Epicondyles of the Humerus* are subcutaneous and are easily recognised; the medial is the more prominent, while the lateral can readily be traced upwards into the lateral epicondylic ridge. The medial epicondyle is the more posterior when the arm is by the side. This does not imply any medial rotation of the humerus, but is due to the fact that its ventral surface, like the ventral surface of the scapula, is directed medially as well as forwards. The line joining the two epicondyles is horizontal, and, in complete extension of the elbow, it passes through the proximal border of the *Olecranon*, which also is subcutaneous. As the elbow is flexed, the olecranon descends, till in full flexion it lies at least an inch distal to the epicondyles. Between the dorsal surface of the olecranon and the overlying skin there is a *bursa*, which is frequently infected, through abrasions of the skin, after falls on the elbow. This may cause cellulitis in the forearm from direct spread. Chronic inflammation of this bursa is not uncommon in miners.

The *Head of the Radius* can be felt on the posterior aspect of the limb. When the forearm is flexed, it lies nearly an inch in front of the lateral epicondyle, the interval between the two being occupied by the capitulum (capitellum) of the humerus. When the forearm is fully extended, the tip of the finger may be inserted into a distinct hollow immediately proximal to the head and behind the radial collateral (external) ligament. This hollow corresponds to the lateral and posterior part of the radio-humeral joint, and immediately proximal to it the subcutaneous posterior aspect of the lateral epicondyle can be made out. If the elbow is grasped by the hand so that the olecranon fits into the palm, while the thumb rests over the head of the radius, the latter will be felt to rotate when the forearm is alternately pronated and supinated.

Muscular Landmarks.—The flexor muscles on the medial side, and the extensor and supinator muscles on the lateral side, bound the *cubital fossa*, a triangular depression in front of the elbow, distal to the intercondylar line. Entering the fossa is the strong *tendon of the biceps*, and the examining finger can readily slip into the depression between this tendon and the brachio-radialis. From the medial border of the tendon the *lacertus fibrosus* (*bicipital fascia*) passes distally and medially to blend with the fascia covering the flexor muscles. It hinders the examination of the depression between the biceps tendon and the flexor muscles, but if the finger is inserted behind its prominent proximal border, the pulsations of the brachial artery can readily be felt.

Superficial Nerves of the Arm, Elbow Region, and Forearm.—The proximal part of the lateral aspect of the arm is supplied by the *Axillary* (*Circumflex*) *Nerve* (C. 5 and 6). Between this area and the lateral epicondyle the skin is supplied by the proximal division of the *Dorsal Cutaneous Nerve of the Forearm* (*Upper External Cutaneous Branch of Musculo-Spiral*) (C. 5 and 6), which arises just before the radial (musculo-spiral) nerve penetrates the lateral intermuscular septum. It at once pierces the deep fascia and associates itself with the cephalic vein. *The Distal Division of the Dorsal Cutaneous Nerve of the Forearm (Lower External Cutaneous Branch of Musculo-Spiral)*

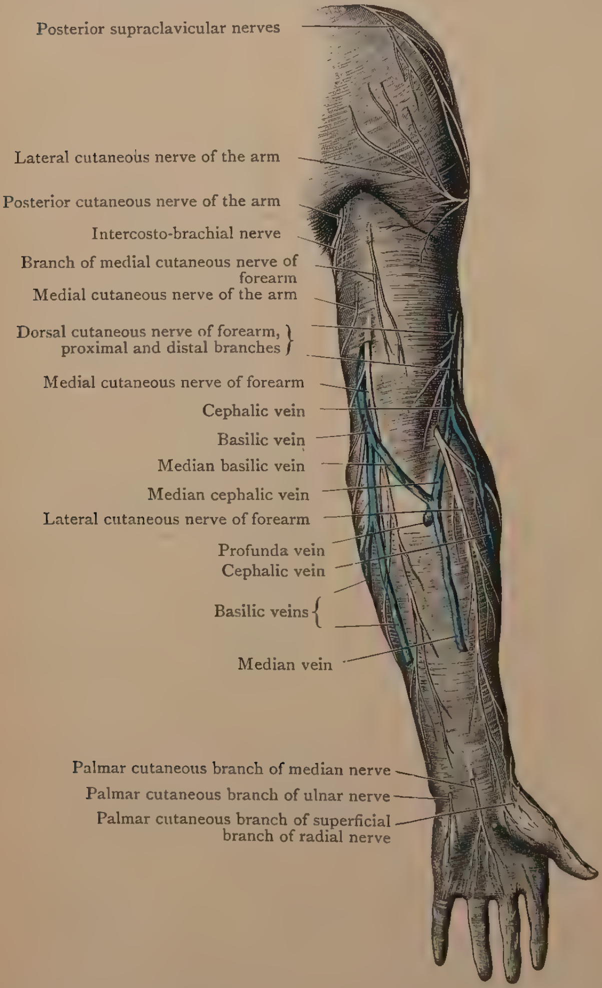

Posterior supraclavicular nerves
Lateral cutaneous nerve of the arm
Posterior cutaneous nerve of the arm
Intercosto-brachial nerve
Branch of medial cutaneous nerve of forearm
Medial cutaneous nerve of the arm
Dorsal cutaneous nerve of forearm, proximal and distal branches
Medial cutaneous nerve of forearm
Cephalic vein
Basilic vein
Median basilic vein
Median cephalic vein
Lateral cutaneous nerve of forearm
Profunda vein
Cephalic vein
Basilic veins
Median vein
Palmar cutaneous branch of median nerve
Palmar cutaneous branch of ulnar nerve
Palmar cutaneous branch of superficial branch of radial nerve

FIG. 12.—The Superficial Nerves and Veins on the Front of the Upper Limb.

(C. 6 and 7), arises just distal to the last-named, runs distally behind the lateral epicondyle and supplies the skin on the back of the forearm as far as the wrist (Fig. 13).

The lateral aspect of the forearm is supplied by the *Lateral Cutaneous Nerve,* which is the terminal part of the *Musculo-*

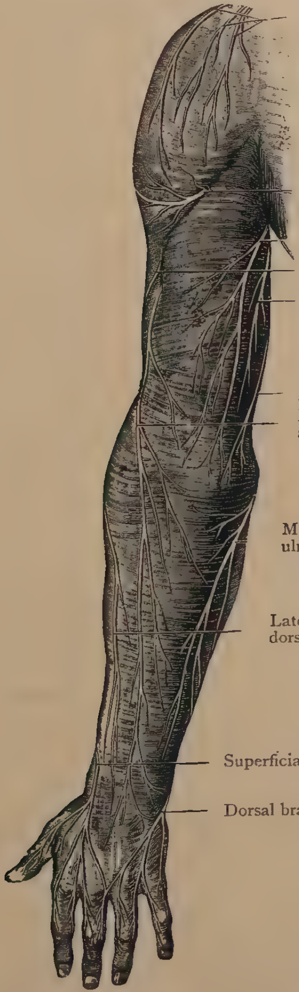

Posterior supraclavicular nerves
Lateral cutaneous nerve of arm
Posterior cutaneous nerve of arm
Dorsal cutaneous nerve of forearm, proximal branch
Intercosto-brachial nerve
Medial cutaneous nerve of arm
Dorsal cutaneous nerve of forearm, distal branch
Medial cutaneous nerve of forearm, ulnar branch
Lateral cutaneous nerve of forearm, dorsal branch
Superficial division of radial
Dorsal branch of ulnar nerve

FIG. 13.—The Superficial Nerves on the Dorsal Aspect of the Upper Limb.

Cutaneous Nerve (C. 5 and 6). After it pierces the deep fascia (p. 42), it crosses the median cephalic vein and divides into volar (anterior) and dorsal branches.

The former supplies the front of the forearm as far as the thenar eminence; the latter winds over the brachio-radialis to supply the posterior surface of the forearm as far as the wrist. It lies lateral to the dorsal cutaneous nerve of the forearm (lower external cutaneous branch of musculo-spiral).

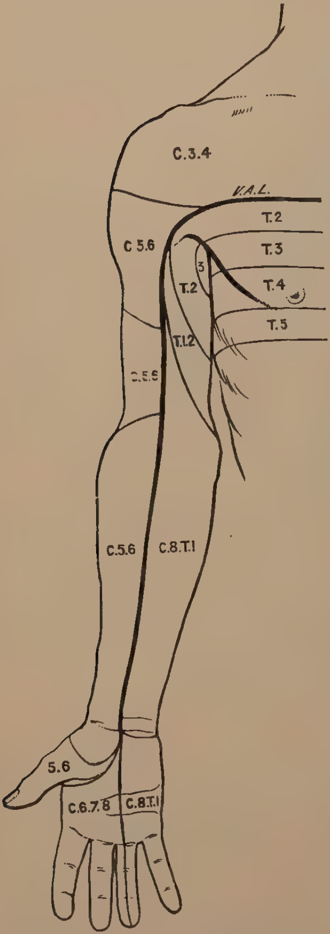


FIG. 14.—Schematic Representation of the Distribution of the Spinal Nerves to the Skin on the Anterior Aspect of the Upper Limb.

V.A.L. Ventral axial line.

The medial aspect of the arm is supplied above by the *Intercosto-brachial Nerve* (T.2), (p. 32), and, more posteriorly, by the *Dorsal Cutaneous Nerve of the Arm* (C. 8) (*Internal Cutaneous Branch of Musculo-spiral*), which arises before the radial nerve enters its groove on the back of the humerus.

Distal to this area the skin is supplied by the *Medial Cutaneous Nerve of the Arm* (*Lesser Internal Cutaneous Nerve*) (T. 1 and 2), as far as the medial epicondyle. The skin covering the biceps is supplied by the *Medial Cutaneous Nerve of the Forearm* (*Internal Cutaneous Nerve*) (C. 8 and T. 1), which pierces the deep fascia at the insertion of the coraco-brachialis and accompanies the basilic vein. Just proximal to the medial epicondyle it divides into volar (anterior) and ulnar (posterior) branches which supply the medial half of the forearm as far as the wrist.

It will be observed that the skin on the lateral aspect of the limb is supplied by the upper nerves of the brachial plexus, and that on the medial side by the lower. The innervation of the limb at an early stage of development provides a useful explanation. At the fourth week of embryonic life the upper limb projects from the side of the neck region as a small bud, which possesses a ventral and a dorsal surface, a cephalic (pre-axial) and a caudal (post-axial) border. The anterior rami (anterior primary divisions) of the lower four cervical and the first thoracic nerves grow out into the bud; C. 5 supplies the pre-axial border, and T. 1 the post-axial. As the limb lengthens, C. 6 and C. 8 reach the respective borders of the bud, but C. 7 becomes situated deeply in its substance and reaches the surface only at the distal part of the limb.

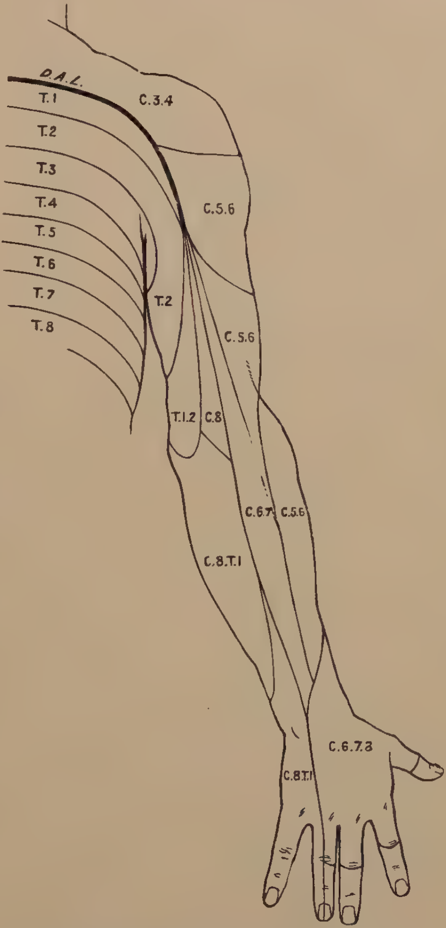


Fig. 15.—Schematic Representation of the Distribution of the Spinal Nerves to the Skin on the Dorsal Aspect of the Upper Limb.

D.A.L. Dorsal axial line.

When wounds or incisions on the lateral aspect of the forearm heal, they may include twigs from the musculo-cutaneous nerve in the cicatrix. The irritation of the nerve reflexly stimulates the segments of the spinal medulla (C. 5 and 6) from which the nerve arises, with the result that muscles supplied by these segments—the biceps and the brachialis (b. anticus)—may be thrown into spasm. In this way the condition of "Bent Arm" arises; and it can be cured only by excision of the cicatrix.

Superficial Veins of Elbow and Forearm.—The superficial veins of the forearm arise from the plexuses of the digits and hand, and, although liable to variation, their arrangement at the elbow is fairly constant. The *Median Vein* begins near the dorsal radial tubercle (p. 66), and winds round the radial border of the forearm. It ends at the apex of the cubital fossa by dividing into the *Median Basilic* and *Median Cephalic* veins, soon after it has received its chief tributary, the profunda, from the deeper structures of the forearm (Fig. 12).

The *Median Basilic* passes proximally and medially, superficial to the lacertus fibrosus (bicipital fascia), and in front of the medial epicondyle it joins the *Basilic vein*, which ascends from the ulnar side of the hand. Thereafter the basilic vein ascends in the medial bicipital furrow as far as the insertion of the coraco-brachialis, where it pierces the deep fascia (p. 34). The *Cephalic vein*, which arises on the radial side of the hand, is joined by the median cephalic in front of the lateral epicondyle. It passes proximally on the deep fascia over the lateral aspect of the biceps brachii and enters the groove between the deltoid and the pectoralis major, which conducts it to the superficial infra-clavicular triangle.

It is important to recognise that most of the venous return from the hand and forearm passes by the profunda to the median and then to the basilic and cephalic veins, which are superficially placed, whereas only a small proportion returns by the venæ comites of the brachial artery.

On this account the venous return is easily controlled, and the arm is therefore suitable for the purpose of Bier's congestive treatment in acute infective conditions.

Bandages, too tightly applied, very easily produce such œdema and pressure that Volkmann's ischæmic contracture or even gangrene of the limb may follow.

Volkmann's Ischæmic Contracture produces a deformity in which the fingers and wrist gradually assume a flexed attitude, owing to an interstitial fibrosis of the flexor muscles of the forearm. When the wrist is passively extended, the flexion of the fingers is increased, as the fibrosed flexor muscles cannot stretch. The extensor muscles become stretched and weakened by the constant flexion of the fingers, and they appear to be paralysed. On flexion of the wrist, which loosens the flexors and overstretches the extensors, it will be found that the extensors of the fingers are able to produce a weak movement, a feature which serves to differentiate the condition from radial (musculo-spiral) paralysis (p. 104).

The median basilic and median cephalic are the veins commonly used for transfusion of saline or for intravenous injection of drugs. They may be rendered prominent by allowing the arm to hang downwards for a few minutes or by applying a bandage round the arm tight enough to constrict the veins without affecting the artery.

The Lymph Vessels of the digits and hand are closely associated with the superficial veins, and the main trunks accompany the bigger veins in the forearm. Those of the ulnar side open into the epitrochlear lymph gland (p. 44), while the median and radial lymph trunks open into lymph glands which lie in the cubital fossa, or, in the absence of these, into the epitrochlear lymph gland. The efferents from these glands follow the course of the basilic vein and terminate in the lateral group of the axillary lymph glands (p. 35). Sometimes the lymph vessels from the lateral three digits pass directly along the radial side of the arm and end in the infra-clavicular (p. 30) or even in the pectoral lymph glands (p. 35).

The Elbow and Proximal Radio-Ulnar Joints.—At the elbow-joint the *Trochlea* and *Capitulum* of the humerus articulate with the *Semilunar Notch* (*Greater Sigmoid Cavity*) of the ulna and the proximal surface of the head of the radius, respectively. At the proximal radio-ulnar joint the medial side of the head of the radius articulates with the *Radial Notch* (*Lesser Sigmoid Cavity*) of the ulna, and the cartilage covering these areas is directly continuous with that which covers the adjoining articular surfaces of the humero-radial and humero-ulnar joints.

The transverse axis of the trochlea slants distally and medially, and is therefore not at right angles to the long axis of the humerus. The semilunar notch (greater sigmoid cavity) is formed by the anterior surface of the olecranon and by the proximal surface of the coronoid process. The transverse axis of the latter forms an angle of less than 90° with the shaft of the ulna, and so the long axis of the humerus and ulna meet at an angle of less than 180° when the forearm is extended and supine. This lateral angulation (Fig. 16) is termed the "Carrying Angle." Masked in pronation, it allows the radius to come into direct line with the humerus in the mid-prone position, and it is with the forearm in this position that the hand is most frequently used. The angles which the long axes of the humerus and ulna make with the transverse axis of the elbow are equal to one another. As a result, when the supinated forearm is fully flexed, the anterior surfaces of the arm and forearm are accurately applied to one another. But, when the supinated forearm is fully flexed (the arm being by the side), the fingers lie over the medial half of the clavicle and not over the point of the shoulder, owing to the position of the humerus (p. 44). To obtain the correct alignment of the arm and to reproduce accurately the carrying angle following fractures into the joint, the limb is adjusted with the arm by the side, the forearm fully flexed but not quite fully supinated, and the fingers in front of the medial half of the clavicle.

The Capsule is attached on the anterior aspect of the humerus to the proximal borders of the coronoid and radial fossæ and to the bases of the epicondyles. Posteriorly, it is attached to the floor of the olecranon fossa, and to its sides as far as the bases of the epicondyles. On the ulna it is attached to the margins of the semilunar notch, except at the radial notch. On the lateral aspect of the joint it blends with the annular ligament.

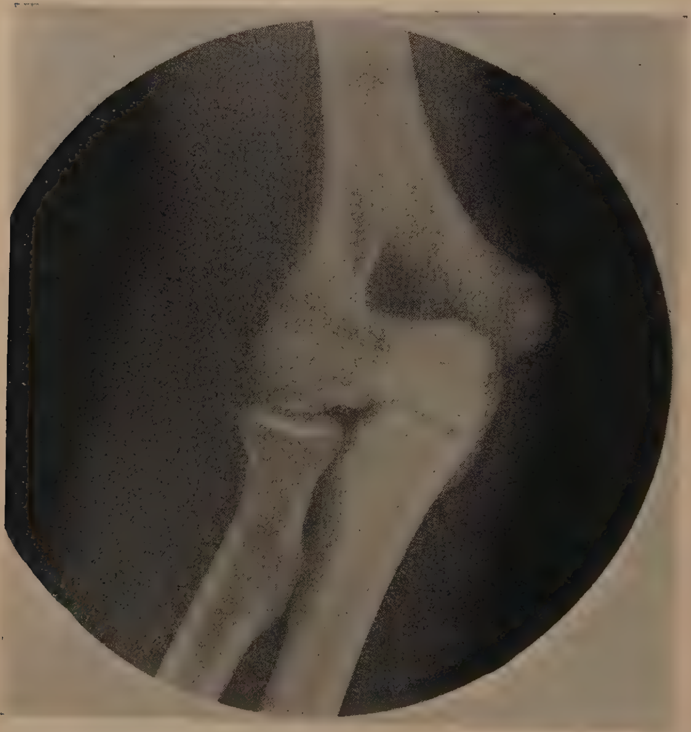


FIG. 16.—Normal Elbow of an Adult Female. Antero-posterior View. The carrying angle is well shown. The increased density of the shadow in the region of the trochlea is caused by the olecranon.

The **Annular (Orbicular) Ligament** surrounds the head of the radius and is attached to the anterior and posterior extremities of the radial notch. Its proximal border blends with the capsule of the elbow, but its distal margin is not attached to bone, and therefore the distal part of the capsule of the elbow and proximal radio-ulnar joints is incomplete. Through the gap left between the neck of the radius and the distal border of the annular ligament the synovial membrane pouches distally for a varying distance (Fig. 17).

The **Anterior and Posterior Ligaments** of the elbow are simply thickenings of the capsule in front and behind. They do not possess great strength, but they are supported by the tendons of the brachialis and the triceps respectively.

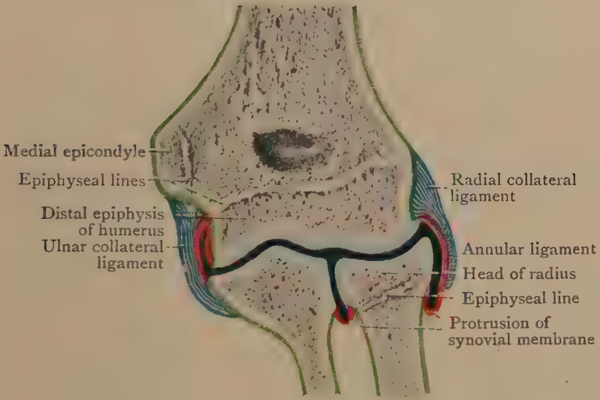

Medial epicondyle
Epiphyseal lines
Distal epiphysis of humerus
Ulnar collateral ligament
Radial collateral ligament
Annular ligament
Head of radius
Epiphyseal line
Protrusion of synovial membrane

FIG. 17.—Frontal Section through the Elbow and Proximal Radio-Ulnar Joints.

Light blue = articular cartilage. Green = periosteum.
Striped blue = ligaments. Red = synovial membrane.

The **Radial Collateral (External Lateral) Ligament** is narrow at its attachment to the lateral epicondyle but is wider distally, where it blends with the annular ligament.

The **Ulnar Collateral (Internal Lateral) Ligament** is attached to the distal aspect of the medial epicondyle. Its anterior fibres pass to the medial border of the coronoid process and its posterior fibres to the medial border of the olecranon, while the intermediate fibres are attached to a strong transverse band which bridges the interval between the two processes.

The **Synovial Membrane** is attached to the margins of the articular cartilages of the humerus, ulna, and radius. It then covers the adjacent bone as far as the attachment of the fibrous capsule, on to which it is reflected. At the distal border of the annular ligament of the radius the membrane pouches downwards for a short distance around the neck of the bone. Little pads of fat fill up the olecranon, coronoid, and radial fossæ, but although they are intra-capsular they are covered by the synovial membrane and therefore remain extra-synovial (Fig. 18). When these fatty pads hypertrophy (lipoma arborescens), portions of them may project into the joint, but they are still covered by a layer of synovial membrane.

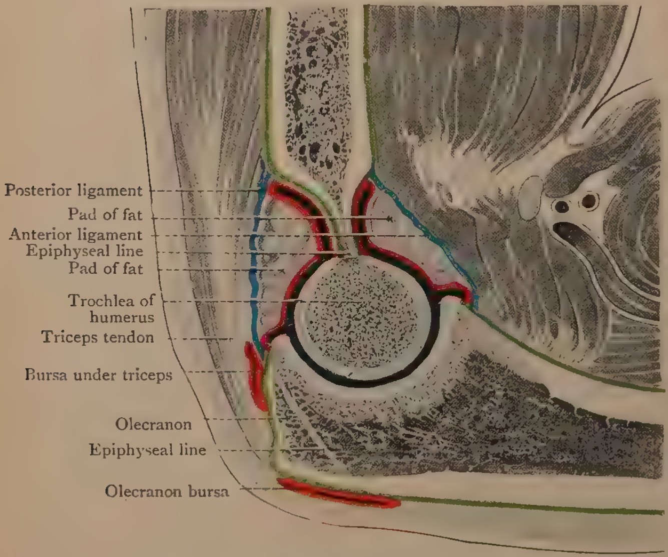

Posterior ligament
Pad of fat
Anterior ligament
Epiphyseal line
Pad of fat
Trochlea of humerus
Triceps tendon
Bursa under triceps
Olecranon
Epiphyseal line
Olecranon bursa

FIG. 18.—Sagittal Section through the Elbow Joint. The synovial membrane lining the joint is shown in *red*, the articular cartilage in *light blue*, and the periosteum in *green*. The pads of fat, though intra-capsular, are extra-synovial.

The *Nerve Supply* of the joint is derived from branches of the Ulnar, Median, Radial (Musculo-spiral), and Musculo-cutaneous nerves.

The presence of fluid in the joint is apparent first on either side of the tendon of the triceps, owing to the weakness of the posterior part of the capsule, and, subsequently, the dimple proximal to the head of the radius becomes obliterated. The deep fascia on the front of the elbow and the lacertus fibrosus (bicipital fascia) are exceptionally strong, and therefore, if sinuses develop in connection with the joint, they will usually be found on one or other side of the triceps tendon.

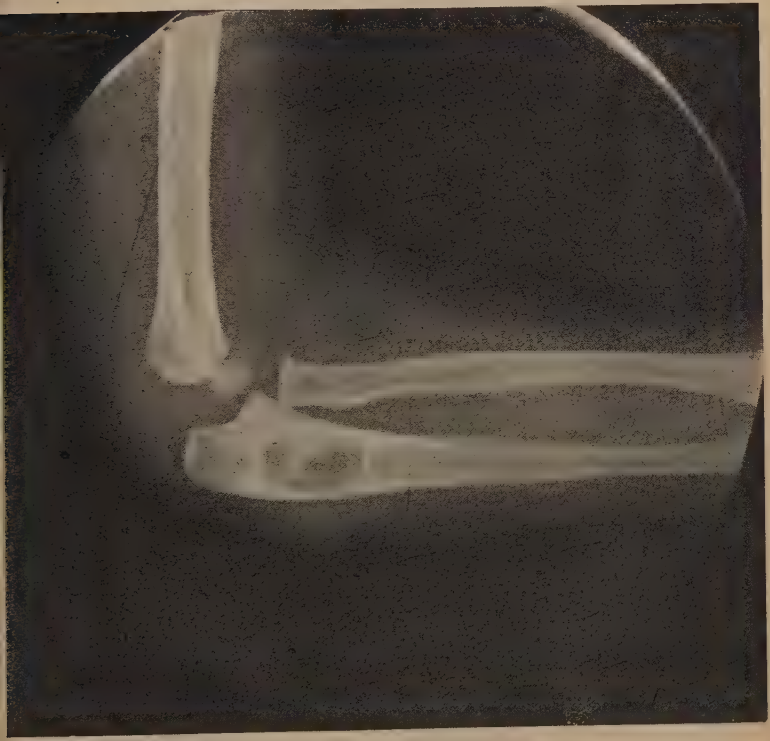


FIG. 19.—Elbow of Child, aged four. Lateral View. The centre of ossification for the capitulum is the only secondary centre present. It lies on a plane anterior to the long axis of the humerus. A tuberculous focus is seen in the proximal part of the shaft of the ulna.

The elbow-joint may be *aspirated* by inserting a trochar from the lateral side, at right angles to the limb, immediately proximal to the head of the radius.

Ossification of the Distal Extremity of the Humerus.—In the infant the whole of the distal extremity of the humerus is cartilaginous. During the second or third year a secondary centre appears for the Capitulum and lateral part of the Trochlea, and this is followed, about the fifth year, by the centre for the Medial Epicondyle. At this period the distal and medial part of the diaphysis grows distally, *separating the Medial Epicondyle from the rest of the Epiphysis* (Fig. 17). During the eleventh and twelfth years centres appear for the Lateral Epicondyle and the remainder of the Trochlea. The true epiphysis consists of the three lateral centres of ossification, which fuse with one another at thirteen or fourteen, and it joins the shaft between the sixteenth and seventeenth years. The actual line of union

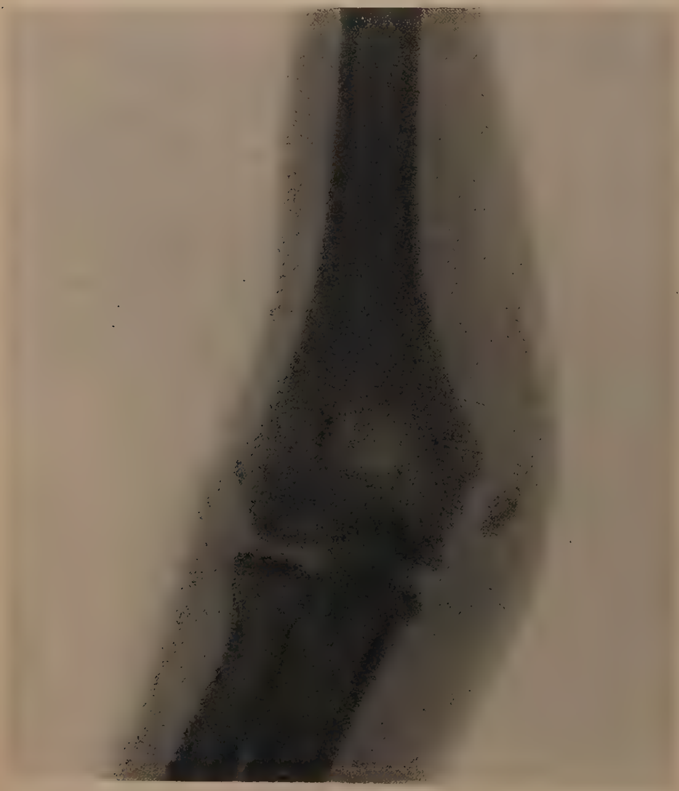


FIG. 20.—Elbow Joint of Boy, aged fourteen. The centres of ossification in the distal extremity of the humerus are well shown.

corresponds to the proximal margin of the articular cartilage and laterally from the point at which the cartilage ceases, to a point immediately proximal to the lateral epicondyle; on the medial side it coincides with the margin of the trochlea (Fig. 17). The medial epicondylar epiphysis joins the diaphysis about one year later.

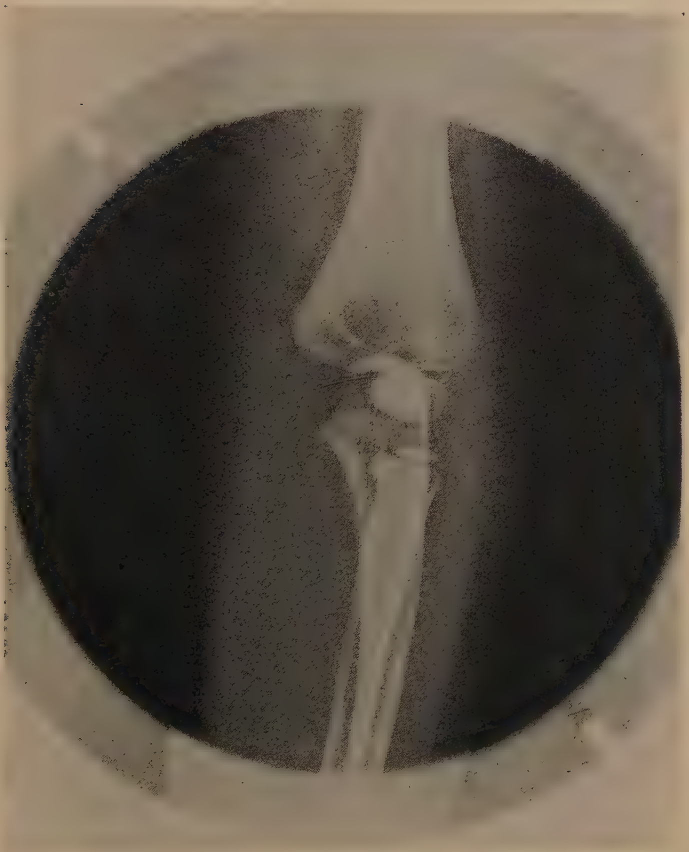


FIG. 21.—Elbow of Child, aged five. The centres of ossification for the capitulum and for the head of the radius can be recognised, but the medial epicondyle has not yet begun to ossify.

Ossification of the Proximal Extremity of the Ulna.—

The formation of the olecranon is due chiefly to the growth of the diaphysis which occurs during childhood. A secondary centre appears in the cartilaginous extremity about the eighth or ninth year. It forms the proximal portion of the olecranon (Fig. 18), but, as a rule, it takes no part in the formation of the articular surface of the semilunar notch (greater sigmoid cavity). It joins the shaft about the seventeenth year.

Dislocation of the elbow is common in childhood, because the bony prominences, which in adults produce an osseously strong joint, are only developing at that period.

Ossification of the Proximal Extremity of the Radius.—In the cartilaginous proximal extremity of the radius a secondary centre appears between four and five, and forms a disc-shaped epiphysis, which joins the shaft between eighteen and twenty. Until this centre begins to enlarge, there is relatively little difference between the circumferences of the head and the neck of the bone. This fact explains the frequency of subluxation of the radius (p. 62) in little children.

The various epiphyses of the elbow have been described in some detail, as a thorough knowledge of them is necessary for the correct interpretation of radiograms of this region. It is not uncommon for the clear area of epiphyseal cartilage to be mistaken for the line of a fracture, if there is any history of injury; and the olecranon has been cut down upon owing to this error.

Separation of the Epiphysis at the distal end of the humerus is the commonest of the more severe injuries of the elbow region which occur during childhood and adolescence. It may be complicated by fracture across the distal and medial portion of the diaphysis. The displacement of the distal fragment is usually backwards, and, owing to the exceedingly strong attachment of periosteum to epiphyseal cartilage, the periosteum is stripped up from the posterior aspect of the distal part of the diaphysis for a varying distance. Unless the replacement is accurate, the stripped periosteum forms a new shaft to the humerus posterior to the existing one, which remains as a prominent exostosis (Fig. 22), and subsequently interferes with flexion by impinging on the coronoid process. As the cartilaginous extremity is translucent to the X-rays, there may be great difficulty in diagnosing this condition in children of less than three years of age, *i.e.* before the secondary ossific centres are present.

Spread of Tuberculous Osteo-Myelitis in the Elbow

Region.—A focus of tubercle situated in the growing region of the diaphysis of the *distal extremity of the humerus* is intra-capsular. It may spread (1) towards the medullary cavity; (2) distally, through the epiphyseal cartilage, into the epiphysis, to erupt subsequently through the articular cartilage into the joint; or (3) if the focus increases in all directions, it will, in spite of the reaction of the periosteum, perforate that membrane where it lines one of the humeral fossæ. The disease is then intra-capsular but extra-synovial, and is in direct relation to the extra-synovial pads of fat (p. 54). It rapidly involves

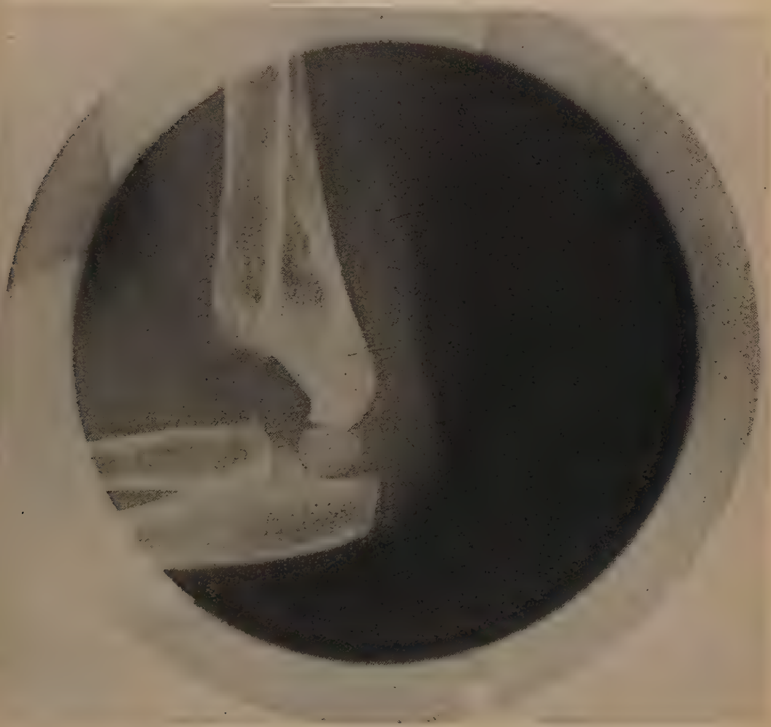


FIG. 22.—Elbow of Child, aged five. Lateral View. The condition shown is subsequent to separation of the distal humeral epiphysis, in which the periosteum had been stripped up from the posterior surface of the diaphysis. Owing to malposition of the fragments, a new shaft has been formed on a posterior plane.

the synovial membrane and attacks the joint. The last-mentioned is the usual direction of spread (Stiles). When a focus is recognised before it has penetrated the periosteum, the distal part of the diaphysis may be resected subperiosteally, without the joint being opened.

Surgical Approach to the Distal Part of the Humerus.—In subperiosteal resection of the distal part of the shaft of the humerus for tuberculous disease, the bone is approached on the postero-lateral aspect of the arm. The *incision* extends from just below the radial (musculo-spiral) groove to the lateral epicondyle. The medial head of the triceps is split and the bone is exposed. After the periosteum has been separated, the humerus is cut through at a level proximal to the disease, and the distal part of the diaphysis is wrenched out. The bone tears away from the epiphyseal cartilage, which is left attached to the epiphysis. Although the capsule is attached to the periosteum beyond the epiphyseal line, the elbow-joint is not opened because the periosteum is firmly attached to the epiphyseal cartilage.

When a tuberculous focus occurs in the **Proximal Extremity of the Radial Diaphysis**, it is *intra-capsular*. Any extension of the disease through the periosteum of the neck will certainly infect the synovial membrane of the elbow-joint, on account of the relations which these structures bear to one another (Fig. 17). Extension in a distal direction will involve the shaft. (See p. 75 for resection of proximal part of radius.)

A tuberculous focus in the **Proximal End of the Ulna** is *extra-capsular*. It may spread (1) forwards through the articular cartilage into the joint; (2) distally into the shaft, or (3) it may perforate the periosteum on the lateral or medial side of the bone and infect the soft parts. The last mentioned is the commonest direction of spread.

The proximal end of the ulna is unsuitable for complete subperiosteal resection as, by removal of the shaft and semilunar notch (greater sigmoid cavity), the elbow-joint is widely opened.

Dislocation of the Elbow.—(*a*) **Posterior.**—This injury results from a fall on the hand, the arm being abducted at the shoulder and extended at the elbow. The line of force passes upwards behind the transverse axis of the elbow-joint, and, as a result, the forearm is hyper-extended. All the ligaments give way, except the annular (orbicular), and the distal extremity of the humerus slips forwards out of the semilunar notch. The coronoid process comes to rest in the olecranon fossa; the head of the radius lies behind the lateral epicondyle; and the distal end of the humerus sinks into the cubital fossa. The arm and forearm meet at an angle of about 120°, but in old-standing cases the angle becomes less pronounced owing to the constant traction of the triceps. The relations of the epicondyles to one another are unchanged, but their relations to the other bony points undergo considerable alteration.

(*b*) **Anterior.**—This rare dislocation results from violence, applied to the olecranon from behind when the elbow is flexed. The triceps is ruptured and the radius and ulna pass forwards, the forearm being flexed by the brachialis and the biceps. All the ligaments except the annular (orbicular) are torn, and the muscles arising from the epicondyles may be injured. Compared with the sound limb, there is an increase in the distance between the lateral epicondyle of the humerus and the styloid process of the radius.

An incomplete variety of this dislocation occurs when the injury is complicated by *fracture of the olecranon.* The small fragment remains in contact with the trochlea, but the remainder of the ulna and the radius pass forwards in front of the distal end of the humerus.

(*c*) **Lateral** and (*d*) **Medial dislocations** occur from falls upon the pronated, outstretched hand. The direction of the displacement depends on whether the line of force is lateral or medial to the mid-point of the transverse axis of the elbow.

The lateral dislocation may be complete, and, if so, all the ligaments, except the annular, are ruptured. More commonly the semilunar notch does not entirely leave the trochlea, and the dislocation is consequently incomplete.

The medial dislocation is always incomplete, as the head of the radius remains partially in contact with the capitulum, though at a different angle, as the long axis of the bone is now directed distally and medially.

Divergent dislocations can occur only after rupture of the annular (orbicular) ligament. They may be either antero-posterior, the radius passing forwards and the ulna backwards, or they may be horizontal, the radius being displaced laterally and the ulna medially.

Reduction of the posterior dislocation may be performed by traction on the forearm and counter-extension of the arm. As soon as the coronoid process is drawn past the distal surface of the trochlea, the forearm is flexed, as the displacement will not recur with the elbow in this position. If the coronoid process hitches in the olecranon fossa, the forearm may be hyper-extended, and, by using the tip of the olecranon as a fulcrum against the distal end of the humerus, the coronoid is lifted out of the olecranon fossa. It can then be drawn distally by traction.

In children, reduction is easily obtained (p. 58) if the surgeon grasps the arm just proximal to the epicondyles in such a way that he can exert the pressure of both thumbs to push the olecranon downwards.

The spasm of the brachialis assists in the replacement, as soon as the tension of the triceps is overcome.

Complications.—The *Ulnar Nerve* may be stretched or bruised at the time of dislocation, especially if the medial epicondyle is broken off (p. 63).

Fracture of the Coronoid Process may complicate the posterior dislocation. Reduction is easy, but the displacement readily recurs. The injury may be mistaken for a supracondylar fracture of the humerus, unless the relations of the bony points are carefully studied.

Fracture of the Epicondyles (p. 63).

Myositis ossificans in the tendon of the brachialis is a complication which not uncommonly follows dislocation of the elbow. The osseous deposit interferes with complete flexion and may or may not remain permanently.

Subluxation of the Radius (p. 58) is produced by sudden traction on the hand or wrist. It is probable that only a part of the head of the radius slips out of the annular (orbicular) ligament; otherwise reduction would be difficult to obtain. When the accident occurs, the forearm is in the position of pronation and the greatest strain is thrown, through the radius, on to the lateral part of the annular ligament. This oblique strain drags the postero-lateral part of the head of the radius through the ligament, leaving the medial half of the head within the joint. Complete downward subluxation is prevented by the interosseous membrane and the ligaments of the distal radio-ulnar joint, and can occur only when these ligaments are injured. The forcible supination, carried out by the surgeon, screws the half-dislocated head back into place again.

Fractures around the Elbow-Joint.—The distal end of the humerus is weakened by the grooving of the trochlea and by the olecranon and coronoid fossæ. It has to withstand the force transmitted through the forearm from falls upon the hand, and in consequence fractures in this situation are very common.

In children, the injury may take the form of a **Separation of the Distal Epiphysis of the Humerus.** In adults, the supracondylar fracture of the shaft frequently radiates through one of the fossæ into the joint, giving rise to the so-called T- or Y-shaped fracture.

The medial epicondyle may be fractured without other injuries. It is displaced distally and forwards by the attached flexor and pronator muscles. Sometimes the line of this fracture is oblique and includes a portion of the trochlea in addition, consequently involving the joint. Through faulty apposition the medial epicondyle may be displaced proximally, changing the transverse axis of the trochlea (p. 51), and subsequently leading to the condition of cubitus varus.

This injury may involve the ulnar nerve, causing neuritis and progressive paresis of the muscles which it supplies (p. 105). Occasionally the symptoms do not appear till many years later, and evidence of injury, of which there is often no history, is obtained only by the X-rays.

Injury to the lateral epicondyle may lead in the same way to the condition of cubitus valgus (see Carrying Angle, p. 51).

Fracture of the Olecranon Process.—The small, proximal fragment usually includes the proximal half of the semilunar notch, and, consequently, the joint cavity of the elbow is involved (Fig. 18). The swelling, which is partly due to the violence, is increased by hæmorrhagic extravasation into the joint, and it may press upon the superficial veins, producing œdema of the forearm and hand. There may be little or no separation of the fragments, in which case they are kept in position by the periosteum, the ulnar collateral (internal lateral) ligament of the elbow, the anconæus, and the common ulnar aponeurosis. When wide separation occurs, the proximal fragment is drawn proximally and backwards by the triceps, and difficulty is experienced in keeping the ends in good apposition. On this account the surgeon frequently has recourse to the operation of wiring. The fragments can be brought together by two wires—one vertical, the other transverse—without interfering with the articular surface (Fig. 23).

Fracture of the Neck of the Radius is a rare accident, and it is difficult to treat owing to the lack of fixation of the head (p. 53), which may become a loose body in the elbow-joint. On pronation and supination, the head of the radius does not rotate in the annular ligament, and the muscles are thrown into spasm. Owing to non-union or to faulty union, movements of the elbow may be so restricted that excision of the head of the bone is rendered necessary. It may be approached by a longitudinal incision over the interval between the anconæus and the extensor carpi ulnaris (Fig. 26).

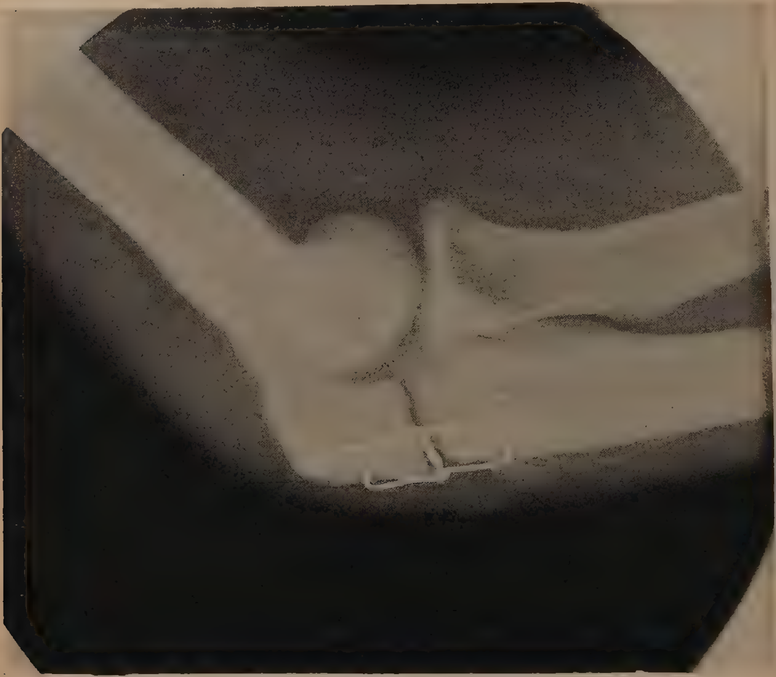


FIG. 23.—Elbow of an Adult Male, showing a Fracture of the Olecranon, wired in Two Planes. Note that the wires do not invade the joint cavity.

Many of the fractures in this region are both intra- and extra-capsular, and the hæmorrhage and effusion into the joint render their diagnosis difficult, even with the assistance of the X-rays.

Surgical Approach to the Elbow-Joint.—Kocher's lateral J-shaped incision is probably the best, since it is planned so as to do least damage and yet gives good preliminary exposure. Proximally, the incision lies immediately behind the lateral intermuscular septum and the radial collateral (external lateral) ligament, and, below, it follows the distal border of the anconæus to the ulna. The annular ligament is cut through on its lateral aspect and the joint is opened.

If the subperiosteal method of resection is adopted, large portions of the removed shafts will be reproduced. Some shortening of the limb may follow, but growth is most active and most prolonged at the shoulder and wrist, and consequently, the results of removal of the epiphyses at the elbow are not so serious as might be expected. The flap, which consists of the skin, fascia, triceps, and anconæus, is elevated subperiosteally from the humerus and the ulna until the ulnar collateral ligament is freed. After the radial collateral ligament has been dealt with similarly, the olecranon is removed. In this way the joint is widely exposed. In dealing with the neck of the radius, care must be taken lest the deep branch of the radial nerve (posterior interosseous nerve) should be injured in its passage through the supinator (s. brevis), and the dependent pouch of the synovial membrane in this situation (Fig. 17) must be totally extirpated. The synovial membrane covering the fatty pads (p. 54) which fill up the humeral fossæ is also completely removed. In this operation the ulnar nerve is not exposed, if the subperiosteal excision is employed.

THE FOREARM AND WRIST.

Bony Landmarks.—The proximal part of the shaft of the **Radius** is surrounded by muscles, but the distal part of its lateral surface and most of its distal extremity can be readily examined. The anterior border of its distal end can be made out as a distinct *ridge* on the front of the forearm about an inch from the thenar eminence. In the hollow immediately proximal to this ridge the radial artery can be felt pulsating, and it may be compressed backwards against the bone. The radial ridge can be traced laterally till it joins the sharp volar (anterior) margin of the bone. When the thumb is extended, the tendons of the abductor pollicis longus (ext. oss. metacarp.) and the extensor pollicis brevis can be felt on the radial side of the wrist, and when the tendons are relaxed, the apex of the **Styloid Process** of the radius is found under cover of them, half an inch distal to the radial ridge. A *tubercle* (*of Lister*) is situated on the dorsal aspect of the distal end of the radius, in the line of the cleft between the index and middle fingers.

The **Dorsal Border of the Ulna** is subcutaneous throughout its whole extent, and, in muscular subjects, its position is indicated by a furrow. The **Styloid Process** of the Ulna can be found by tracing the dorsal border distally. It is placed on the postero-medial aspect of the head and lies on a plane a quarter to half an inch proximal to the styloid process of the radius. It corresponds to the level of the wrist-joint. When the hand is flexed, the rounded **Head** of the Ulna can be felt just proximal to the level of the radial ridge by displacing the tendon of the flexor carpi ulnaris either to the ulnar or to the radial side. When the hand is prone, the lateral surface of the head stands out prominently on the ulnar side of the back of the wrist.

The **Tubercle of the Navicular (Scaphoid)** is felt about three-quarters of an inch distal to the radial ridge at the proximal border of the thenar eminence. If the most distal skin crease at the wrist is followed, it will be found to cross the tubercle of the navicular, on the radial side, and the **Pisiform Bone**, on the ulnar side. This latter bone is most easily identified by allowing the hand to hang in a passively flexed position to relax the flexor carpi ulnaris, as it may then be pinched between the examining finger and thumb and made to glide on the os triquetrum (cuneiform). The **Hook of the Hamate (Unciform)** lies one finger's breadth distal to the pisiform and on a line with the ulnar border of the ring finger. On deep palpation the superficial division of the ulnar nerve may be rolled to and fro over the prominence. The **Ridge on the Os Multangulum Majus (Trapezium)** is placed immediately distal to the navicular tubercle.

Muscular Landmarks.—The muscular mass in the proximal and lateral part of the forearm consists of the **Brachio-Radialis** and the **Extensor Carpi Radialis Longus** and **Brevis**, which arise from the lateral epicondylic ridge and the lateral epicondyle. The medial margin of this group is indicated by a line drawn from the tendon of the biceps to the styloid process of the radius. When resistance is offered to flexion of the elbow, the brachio-radialis stands out prominently on the lateral aspect of the forearm.

The individual **Flexor** and **Pronator** muscles cannot be clearly distinguished proximally, as they are closely bound together by the deep fascia. Nearer the wrist, however, certain of the tendons provide important surgical landmarks. The largest and most prominent tendon is that of the **Flexor Carpi Radialis**, which lies just medial to the navicular tubercle. In flexion of the wrist the **Palmaris Longus** tendon, absent in 10 per cent, stands out on the ulnar side of the flexor carpi radialis. It is the guide to the median nerve, which lies immediately behind it, or to its radial side, in the distal part of the forearm. The tendon of the **Flexor Carpi Ulnaris** can be gripped between the fingers and thumb by inserting the fingers on the medial border of the forearm opposite the distal end of the ulna. It may then be traced to its insertion into the pisiform bone.

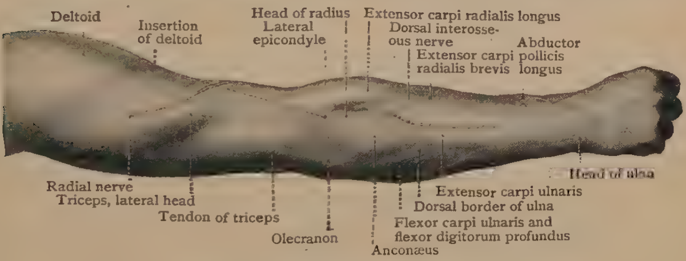

Deltoid
Insertion of deltoid
Head of radius
Lateral epicondyle
Extensor carpi radialis longus
Dorsal interosseous nerve
Abductor pollicis longus
Extensor carpi radialis brevis
Head of ulna
Radial nerve
Triceps, lateral head
Tendon of triceps
Olecranon
Extensor carpi ulnaris
Dorsal border of ulna
Flexor carpi ulnaris and flexor digitorum profundus
Anconæus

FIG. 24.—Surface Landmarks on the Dorsal Aspect of the Superior Extremity.

A line drawn from the lateral epicondyle to the dorsal radial tubercle demarcates the **Radial Extensors of the Wrist** from the **Extensor Digitorum Communis.** One inch from its proximal extremity, it crosses the head of the radius, and at a point two inches lower down, the dorsal interosseous nerve emerges from the substance of the supinator (brevis). In its distal third, the line is crossed obliquely by the muscular bellies of the **Abductor Pollicis Longus (Ext. Oss. Metacarp.)** and the **Extensor Pollicis Brevis.** These muscles lie superficial to the radial extensor tendons of the wrist and are thrown into relief on dorsi-flexion of the hand.

On the lateral aspect of the wrist, a triangular depression is visible when the thumb is extended. It is bounded antero-laterally by the tendons of the **Abductor Pollicis Longus** and the **Extensor Pollicis Brevis** and dorso-medially by the **Extensor Pollicis Longus.** The floor of this fossa is crossed obliquely by the second part of the radial artery (p. 92).

On the back of the wrist the tendons of the Extensor Carpi Radialis Longus and Brevis can be seen when the fist is tightly clenched, and they can be traced to their insertions into the bases of the second and third metacarpal bones respectively.

Muscles of the Forearm and their Relations to Fractures.—The superficial group of flexors and pronators arises mainly from the medial epicondyle of the humerus. They pass with varying degrees of obliquity down the forearm and are all, with the exception of the flexor carpi ulnaris, supplied by branches given off from the trunk of the Median Nerve (C. 6), just distal to the elbow-joint.

The **Pronator Teres**, which has in addition a deep head of origin from the coronoid process, is the most lateral and most obliquely directed of this group. It is inserted into the middle of the lateral surface of the radius and is thus a powerful pronator of the forearm, while it is also a flexor of the elbow. In tennis-players this muscle is frequently overstretched or strained.

Fractures of the Bones of the Forearm.—Fractures from indirect violence may affect both bones or the radius alone. They occur from falls on the hand, and only a small part of the shock is directly transmitted to the ulna. The greater part is communicated to the expanded distal end of the radius and passes upwards to the humerus. Only a small degree of the shock is transmitted from the radius to the ulna by the interosseous membrane, the fibres of which are mainly directed distally and medially. Fracture of the shaft of the ulna alone is always due to direct violence and tends to be compound, as the dorsal border of the bone is subcutaneous in its whole extent.

In **Fractures between the Radial (Bicipital) Tuberosity and the Insertion of the Pronator Teres**, the small proximal fragment is flexed and supinated by the biceps. The distal fragment is pronated by the pronator muscles and its proximal end is tilted towards the ulna by the brachio-radialis and the pronator teres. The proximal fragment is difficult to control owing to its small size, and it is necessary to bring the distal fragment into line with it by flexing the elbow and supinating the hand.

In **Fractures immediately Distal to the Insertion of the Pronator Teres**, the proximal fragment is pronated and slightly flexed. The supinating action of the biceps is counteracted by the pronator teres, which acts at a greater mechanical advantage. The distal fragment is pronated by the pronator quadratus, and its proximal end is tilted towards the ulna as in the previous fracture. In this case the proximal fragment is long enough to be controlled, and the forearm is put up in the mid-prone position, since the distance between the ulna and radius is normally greatest in this position. Ulnar flexion of the hand helps to tilt the proximal end of the distal fragment away from the ulna.

The Superficial Muscles of the Forearm.—The *Flexor carpi radialis* and *Palmaris longus* both become tendinous about the middle of the forearm. The palmaris longus tendon is rather longer and considerably narrower than that of the flexor carpi radialis. Both muscles, when acting with their groups, are powerful flexors of the wrist and weak flexors of the elbow. When the flexor carpi radialis acts alone, it produces flexion and radial deviation at the wrist; when it acts along with the radial extensors, radial deviation alone takes place.

The *Flexor digitorum sublimis* (p. 84) lies deep to the preceding tendons and partly to their ulnar side. The individual tendons arise in the distal third of the forearm, and pass behind the transverse carpal (anterior annular) ligament. It is primarily a flexor of the proximal inter-phalangeal joints, and secondarily a flexor of the metacarpo-phalangeal, wrist, and elbow-joints.

The *Flexor carpi ulnaris* (p. 67) is the most medially placed muscle of this group, and is supplied by the ulnar nerve (C. 8 and T. 1). When acting with its group, it helps to flex the wrist and elbow-joints, but, when acting with the extensor carpi ulnaris, it produces ulnar deviation of the hand.

Ulnar Nerve.—The *course* of the Ulnar Nerve may be indicated by drawing a line from the medial epicondyle to the lateral margin of the pisiform. In the proximal part of the forearm the nerve is almost subcutaneous and may be rolled to and fro against the ulna. It can be exposed by a vertical incision through the skin and fascia behind the medial epicondyle, and is found in contact with the medial side of the elbow-joint.

As the result of sudden violent flexion of the elbow, the deep fascia over it is sometimes torn and the ulnar nerve slips forwards round the medial epicondyle. This dislocation of the nerve may require operative interference.

After supplying the joint, the ulnar nerve passes between the two heads of the flexor carpi ulnaris and almost immediately gives off branches to supply that muscle and the medial part of the flexor digitorum profundus. It runs downwards in front of the latter and it is covered by the flexor carpi ulnaris in the

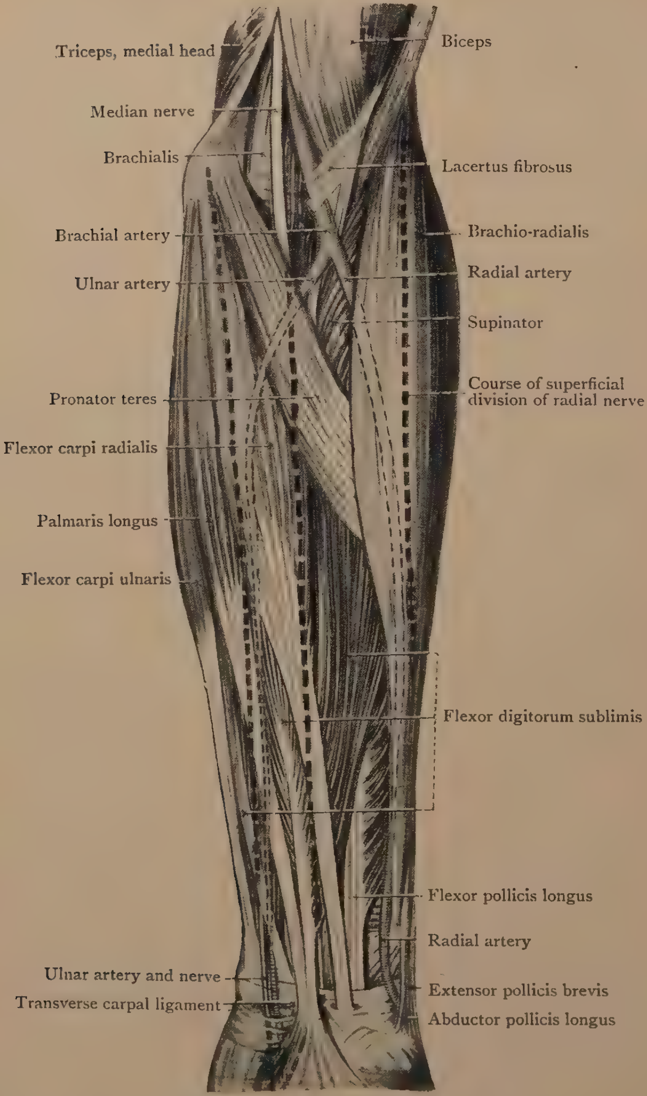

Triceps, medial head
Biceps
Median nerve
Brachialis
Lacertus fibrosus
Brachial artery
Brachio-radialis
Ulnar artery
Radial artery
Supinator
Course of superficial division of radial nerve
Pronator teres
Flexor carpi radialis
Palmaris longus
Flexor carpi ulnaris
Flexor digitorum sublimis
Flexor pollicis longus
Radial artery
Ulnar artery and nerve
Transverse carpal ligament
Extensor pollicis brevis
Abductor pollicis longus

FIG. 25.—The Anterior Aspect of the Forearm, after the removal of all the Structures down to and including the Deep Fascia. The courses taken by the nerves and arteries are indicated by the interrupted lines.

proximal two-thirds of the forearm. Distally it again becomes superficial, lying between the most medial tendon of the flexor digitorum sublimis, on the radial side, and the tendon of the flexor carpi ulnaris, on the ulnar side. At the junction of the proximal and middle thirds of the forearm, it becomes associated with the ulnar artery, which lies close to its lateral side throughout the remainder of their course in this region.

About three inches from the pisiform, the ulnar nerve gives off *palmar* (p. 82) and *dorsal cutaneous branches*. The latter passes backwards below the styloid process of the ulna, crosses the medial surface of the os triquetrum (cuneiform) and gains the dorsum of the hand, where it supplies the little and ring fingers and the ulnar side of the middle finger (p. 86). It runs some risk of being cut in the ulnar incision for excision of the wrist.

Ulnar Artery.—In *ligature* of the ulnar artery in its distal two-thirds, the incision should be made in the line of the ulnar nerve. In the middle third, the flexor carpi ulnaris, which overlies it, must be retracted to the medial side. The course of the proximal third is indicated by a line drawn from the termination of the brachial artery (p. 43) to the point where the ulnar artery becomes associated with the ulnar nerve. As it lies deeply under cover of the superficial group of muscles and is crossed close to its origin by the median nerve, the artery is rarely tied in this part of its course.

Branches.—The *volar* and *dorsal ulnar recurrent* (p. 44) branches arise near the origin of the ulnar artery.

The *Common Interosseous* arises more distally and at once divides into *Volar* (*Anterior*) and *Dorsal branches*. The former runs distally in front of the interosseous membrane and communicates with the volar carpal arch. It pierces the membrane at the proximal border of the pronator quadratus and anastomoses with the dorsal carpal arch and the dorsal interosseous artery. The latter passes backwards proximal to the membrane to supply the extensor muscles, and becomes associated with the dorsal interosseous nerve.

The Superficial (Radial) Branch of the Radial (Musculo-Spiral) Nerve arises in front of the lateral epicondyle under cover of the brachio-radialis. It approaches the radial artery and lies close to its lateral side in the middle third of the forearm. About 3½ inches from the styloid process of the radius the nerve leaves the artery to gain the dorsum of the wrist by passing under cover of the brachio-radialis. Here it is joined by communicating twigs from the dorsal branch of the musculo-cutaneous and from the dorsal cutaneous nerve of the forearm (lower external cutaneous branch of the musculo-spiral nerve). It is a purely sensory nerve and terminates on the back of the hand by supplying the skin on the dorsal aspects of the thumb, index, and the radial side of the middle finger. Injuries to this nerve are discussed on p. 104.

The dorsal digital nerves do not reach the tips of the fingers but end over the second phalanges; the remainder of the dorsal surface is supplied by the digital nerves of the palm.

Radial Artery.—The *course* of the radial artery may be indicated by a line drawn from the termination of the brachial artery (p. 43) to the navicular tubercle. In the proximal two-thirds of its course it will be found under cover of the brachio-radialis. In the proximal third it lies on the supinator, and the superficial (radial) branch of the radial (musculo-spiral) nerve approaches it from the lateral side. In the middle third it lies on the pronator teres and the radial head of the flexor digitorum sublimis, while the nerve is close to its lateral side. The distal third of the artery is subcutaneous and lies upon the flexor pollicis longus and the radius (Fig. 25).

It gives off the **radial recurrent** (p. 44) near its origin, and the **superficial volar** in the distal part of the forearm. The latter runs through or over the short muscles of the thumb to join the ulnar artery and complete the superficial palmar arch (Fig. 30).

If the radial or ulnar artery is severed in more than one place, all the cut ends must be tied, as the muscular branches of the radial, ulnar, and volar (anterior) interosseous arteries anastomose very freely throughout the forearm. When the radial artery is wounded at the wrist, both ends must be ligatured, owing to the free anastomosis in the hand (p. 86).

The **Median Nerve**, which enters the forearm between the superficial and deep heads of the pronator teres (p. 68), can be indicated by a line, drawn from a point midway between the medial epicondyle and the biceps tendon to a point at the wrist, slightly to the medial side of the tendon of the flexor carpi radialis. It lies between the superficial and deep groups of muscles, and is bound down to the deep surface of the flexor digitorum sublimis. It supplies the superficial group (p. 69), with the exception of the flexor carpi ulnaris, and by means of its volar interosseous branch it supplies the deep muscles of the front of the forearm. Injuries of the nerve are discussed on p. 106.

The **Deep Group of Muscles** (*Flexor pollicis longus, Flexor digitorum profundus,* and *Pronator quadratus*) is supplied by the volar interosseous branch of the median nerve (C. 7, 8, and T. 1), with the exception of that portion of the flexor digitorum profundus destined for the ring and little fingers, which is supplied by the ulnar nerve (C. 8 and T. 1).

The Extensor and Supinator Muscles. — The *Brachio-radialis,* which is inserted into the distal part of the lateral surface of the radius, and the *Extensor carpi radialis longus* are both supplied by the radial (musculo-spiral) nerve (C. 5 and 6, C. 6 and 7, respectively). The former is a flexor of the forearm; in the movement of supination it assists until the mid-prone position is reached, and it also assists pronation from the supine to the mid-prone position.

The *Supinator* (S. brevis) winds round the posterior aspect of the proximal part of the radius and is thus a powerful supinator. It is supplied by the deep branch (posterior interosseous) of the radial (musculo-spiral) nerve (C. 6).

The *Anconæus* covers the posterior aspect of the humero-radial joint, and is supplied by a branch from the radial (musculo-spiral) nerve (C. 7 and 8).

The **Superficial Group of Extensors** arises from the distal part of the anterior aspect of the lateral epicondyle of the humerus, and they are supplied by the dorsal interosseous nerve (C. 6, 7, and 8).

This group comprises the *Extensor carpi radialis brevis* (p. 67), the *Extensor digitorum communis* (p. 91), the *Extensor digiti quinti proprius* (p. 91), and the *Extensor carpi ulnaris* (pp. 69, 81).

The **Deep Group of Extensors** arises from the dorsal surfaces of the radius and ulna. They are all supplied by the dorsal interosseous nerve (C. 6, 7, and 8).

The *Abductor Pollicis Longus* (*extensor ossis metacarpi pollicis*) (pp. 67, 75) is inserted into the base of the metacarpal bone of the thumb. It extends and helps to abduct the thumb at the carpo-metacarpal joint.

The *Extensor Pollicis Brevis and Longus* (pp. 68, 75) are inserted into the bases of the first and second phalanges respectively. Primarily they are extensors, but they also aid in adduction of the thumb.

The *Extensor Indicis Proprius* (p. 91).

The **Dorsal Interosseous Nerve** reaches the back of the forearm by winding round the neck of the radius, in the substance of the supinator (s. brevis), its course being at right angles to the direction of the muscle fibres. On leaving the muscle (p. 67) the nerve breaks up into branches which are distributed to the remaining muscles on the back of the forearm.

Surgical Approach to the Bones of the Forearm.—The **Ulna** may be exposed readily in any part of its extent by incisions along its subcutaneous dorsal border.

The **Radius** may be exposed by incisions along the line which separates the radial extensors of the wrist from the extensor digitorum communis (p. 67).

(*a*) *Distal Third.*—At its proximal end the incision exposes

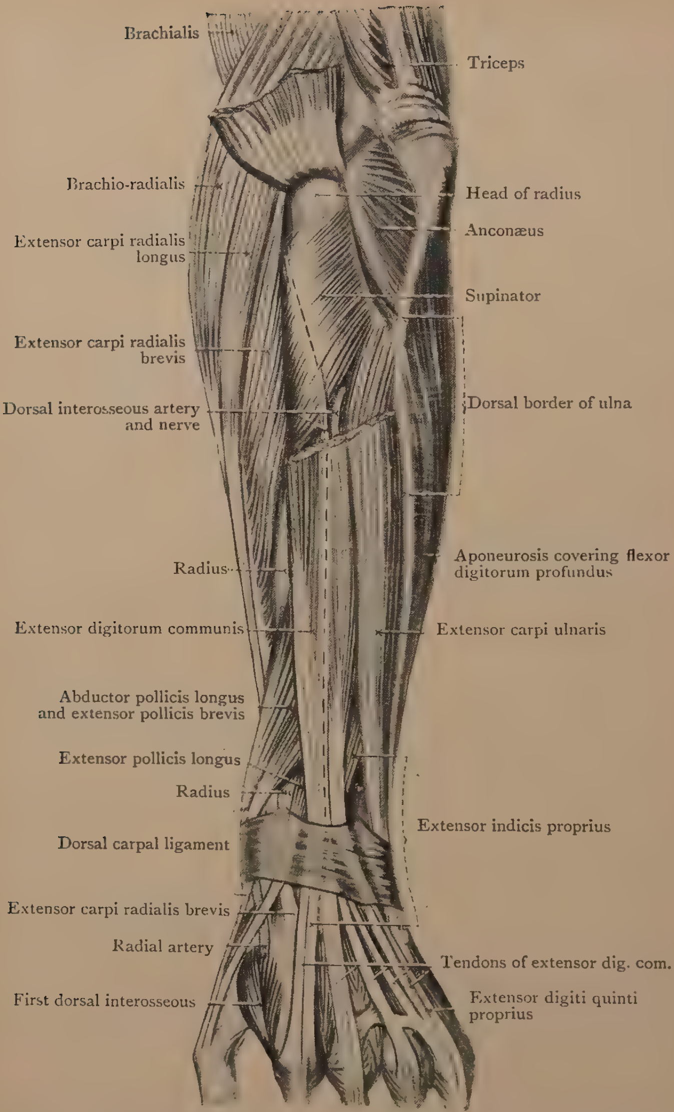

Brachialis
Triceps
Brachio-radialis
Head of radius
Anconæus
Extensor carpi radialis longus
Supinator
Extensor carpi radialis brevis
Dorsal interosseous artery and nerve
Dorsal border of ulna
Aponeurosis covering flexor digitorum profundus
Radius
Extensor digitorum communis
Extensor carpi ulnaris
Abductor pollicis longus and extensor pollicis brevis
Extensor pollicis longus
Radius
Extensor indicis proprius
Dorsal carpal ligament
Extensor carpi radialis brevis
Radial artery
Tendons of extensor dig. com.
First dorsal interosseous
Extensor digiti quinti proprius

FIG. 26.—The Muscles on the Dorsal Aspect of the Forearm. The course of the dorsal interosseous nerve, where it is not exposed to view, is indicated by the interrupted line. The extensor digitorum communis, digiti quinti proprius, and carpi ulnaris, have been divided and their proximal parts elevated.

the extensor pollicis brevis and the abductor pollicis longus as they cross the tendons of the radial extensors of the wrist. The extensor digitorum communis is exposed on the ulnar side of the incision and is retracted medially. When the other muscles and tendons mentioned above are retracted laterally, the distal part of the radius is exposed where it is devoid of muscular attachments. In tuberculous osteo-myelitis the distal part of the diaphysis may then be excised by dividing it proximal to the level of the disease—the periosteum having been stripped off—and by wrenching it away from the epiphyseal cartilage, which remains attached to the epiphysis. The capsule of the wrist joint is uninjured (Fig. 27).

(*b*) *Middle Third.*—The extensor pollicis brevis and the abductor pollicis longus are exposed at the distal end of the wound and are retracted distally and to the ulnar side. The radial extensors of the wrist are retracted laterally, and the bone is exposed between the origin of the abductor longus and the insertion of the pronator teres.

(*c*) *Head and Proximal Third.*—When the extensor digitorum communis is separated from the radial extensors of the wrist at this level the supinator is exposed and must be divided below and parallel to the dorsal interosseous nerve (p. 73). In subperiosteal resection of this part of the radius for tuberculous osteo-myelitis, the bone is cut through distal to the level of the disease and the proximal part is wrenched away. The cartilaginous head of the radius, with the epiphysis if it has developed, is wrenched away with the shaft, as it is attached only to the synovial membrane of the elbow-joint and possesses no special ligamentous connections (Fig. 17). In this resection, therefore, the cavity of the elbow-joint is widely opened.

The Distal Radio-Ulnar Joint.—The ulna is excluded from the wrist-joint by a triangular fibro-cartilage—the **articular disc**—which is attached by its apex to the base of the styloid process of the ulna and by its base to the medial margin of the distal end of the radius. The **capsule** is weak and loose, to permit of pronation and supination, and the synovial membrane bulges proximally between the two bones *beyond the level of the distal epiphyseal lines*. Occasionally the articular disc is perforated, and the synovial membrane becomes continuous with that of the wrist-joint.

The Radio-Carpal Joint or Wrist-Joint.—The proximal surface of the proximal row of carpal bones forms a surface which is convex from side to side and fits into a correspondingly concave surface provided by the carpal aspect of the radius and the articular disc. In this way radial and ulnar deviation of the hand are rendered possible. The **capsule** is strengthened by :

(1) The **Volar and** (2) **Dorsal Radio-Carpal Ligaments,** which are attached to the margins of the articular surfaces ; they are weak bands, but they receive additional support from the flexor and extensor tendons.

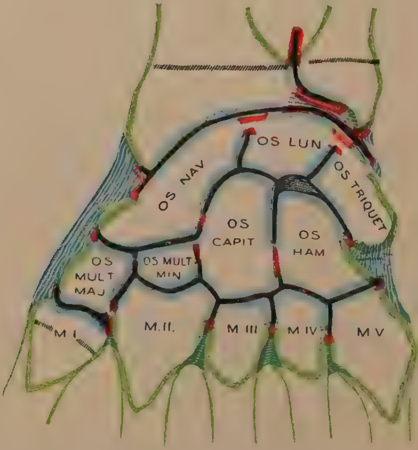


Fig. 27.—Section through the Carpus, to show the various Joint Cavities.

Light blue = articular cartilage.
Striped blue = ligaments.
Green = periosteum.
Red = synovial membrane.

(3) The **Radial Collateral (External Lateral) Ligament** passes from the tip of the radial styloid to the lateral surface of the navicular and is crossed by the second part of the radial artery.

(4) The **Ulnar Collateral (Internal) Ligament** is attached to the tip of the ulnar styloid and to the medial side of the triquetrate (cuneiform) bone. It is on these collateral ligaments that the strength of the joint depends.

The **Synovial Membrane** lines the interior of the capsule closely ; it requires no special description.

Aspiration of the joint may be carried out immediately distal to the tip of the styloid process of the ulna between the extensor and flexor carpi ulnaris tendons.

Colles' Fracture occurs from a fall on the outstretched hand. According to Chiene, the forearm is at an angle of less than 60° to the horizontal when the palm of the hand strikes the ground. The line of force cuts through the distal end of the radius instead of passing along the bone, as it does if the forearm is at an angle of more than 60° to the ground when the injury occurs. Impaction of the proximal fragment into the distal is not uncommon, as the fracture is transverse and occurs through the spongy tissue of the distal end of the bone. The line of force drives the distal fragment *backwards* and tends to thrust it proximally, but the medial edge of the distal end of the radius is attached to the ulna by the triangular articular disc (p. 75), which slips backwards over the head of the latter bone. The styloid process of the radius swings round the arc of a circle whose radius is the length of the triangular articular disc, together with the width of the lower end of the radius. In this way the hand is deviated to the radial side, and the displacement becomes three-fold. When the styloid processes are compared (p. 66), they are found to be on the same level or the radial is the more proximal.

If the ulnar styloid also is fractured, then the displacement is backwards and upwards, but the upward displacement is proportionately greater than in the typical Colles' fracture. **Smith's Fracture** (reversed Colles') occurs from a fall on the back of the hand, the wrist being flexed. The line of force cuts through the anterior surface of the distal end of the radius and the distal fragment is thrust *forwards* and proximally. The hand is deviated to the radial side as in Colles' fracture and for the same reason.

Ossification of the Distal Ends of the Radius and Ulna.—Secondary centres for the distal ends of the Radius and Ulna appear about the third and sixth years, respectively. The distal epiphyses of both bones include the styloid processes and the articular areas. Growth continues longer in the wrist region than it does at the elbow, and the distal epiphyses do not unite till between twenty and twenty-four.

Separation of the distal epiphyses of the radius and ulna may occur between the ages of seven and twenty. Owing to the line of attachment of the capsule of the wrist (p. 76), this injury does not open into the joint.

Owing to trauma or disease, growth may cease prematurely in one bone, but not in the other. As the healthy bone increases in length, the hand gradually becomes deviated to the affected side.

Carpal Joints.—With the exception of the carpo-metacarpal joint of the thumb (p. 84) and the joint between the pisiform and the os triquetrum (cuneiform), all the inter-carpal, carpo-

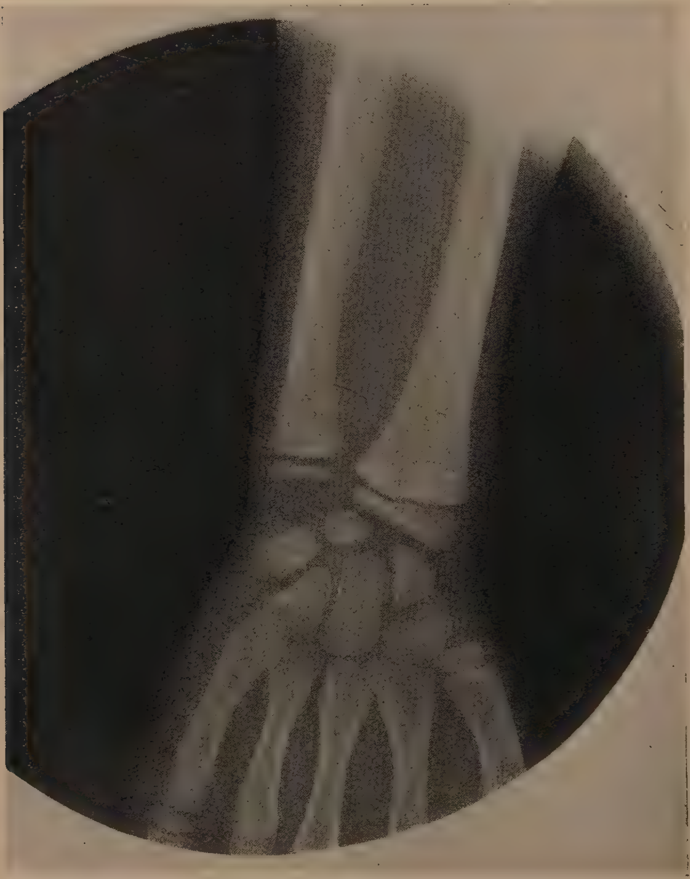


FIG. 28.—Carpus of an Adolescent, aged sixteen. The centres of ossification for all the carpal bones are present, but those for the os multangulum minus and the pisiform are obscured by the os multangulum majus and the os triquetrum, respectively. Observe the epiphysis of the first metacarpal bone.

metacarpal, and inter-metacarpal joints have a common joint cavity lined with a single synovial membrane. Their volar (palmar) and dorsal ligaments are continuous with the corresponding ligaments of the radio-carpal joint (p. 75).

Ossification of the Carpus.—At the end of the first year centres appear for the capitate (os magnum) and hamate (unciform) bones. These are followed by centres for the triquetrate (cuneiform), third year; the lunate (semilunar), fifth year; the greater multangular (trapezium), sixth year; the navicular (scaphoid), sixth year; the lesser multangular (trapezoid), seventh year; and the pisiform about the tenth year.

Spread of Tuberculous Disease in the Wrist Region.—The capsules of the distal radio-ulnar and the radio-carpal joints do not encroach on the diaphyses, and, consequently, tuberculous disease in the distal ends of the diaphyses of the radius and ulna is *extra-capsular*. When it breaks out under the periosteum, it does not commonly spread distally to the joints, unless it erupts in the region where the synovial membrane of the distal radio-ulnar joint pouches proximally between the two bones (p. 75).

The carpal bones are really within the capsule of the wrist-joint, and tuberculous disease arising in them is *intra-capsular* and readily reaches the joint by penetrating the articular cartilage. If the disease spreads forwards or backwards, perforating the ligaments, the synovial sheaths of the tendons become affected; but a sympathetic effusion may occur into the sheaths while the disease is still confined to the joint, and it may set up adhesions, which limit the movements of the muscles concerned.

Surgical Approach to the Wrist-Joint.—Pyogenic infections of the wrist-joint tend to point on the dorsal aspect, to the radial or ulnar side of the tendon of the extensor quinti digiti proprius. An incision immediately to the ulnar side of the tendon of the extensor carpi ulnaris affords the best drainage when the forearm is subsequently placed in the mid-prone position.

In extensive tuberculous disease the **Dorso-Ulnar Incision** (Kocher) offers the best approach, and little damage is done to the tendons if the subperiosteal or the subcortical method is adopted in elevating the dorsal ligaments of the wrist and carpus. Through the space obtained by first excising the triquetrate (cuneiform) bone, the surgeon is able to divide the hook of the hamate. This process and the pisiform are left behind whenever possible, as they provide attachments for the muscles of the hypothenar eminence and for the transverse carpal (anterior annular) ligament. The remainder of the carpus may then be removed piecemeal, but, if practicable, the greater multangular bone (trapezium), which gives attachment to the transverse carpal ligament, is left behind. Further, the separate carpo-metacarpal joint of the thumb, which is not necessarily affected by the disease, is opened into when the greater multangular bone is removed, and the subsequent movements of the thumb (p. 84) are seriously restricted. After removal of the carpus, the extremities of the radius, ulna, and metacarpals may be dislocated into the wound and resected, if necessary. The wrist is subsequently dorsi-flexed, lest the powerful flexors should overstretch the weaker extensor muscles.

In **Dislocation of the Capitate Bone** (**Os Magnum**) the head of the bone projects dorsally, opposite the base of the third metacarpal, and the deformity is increased on flexion of the hand.

The **Lunate** (**Semilunar**) **Bone may be dislocated forwards** by forcible extension of the hand. In this case the ulnar nerve may be injured.

The **Navicular Bone may be fractured** at its narrowest part when it is driven against the distal end of the radius by the rounded head of the os capitatum (os magnum). Forward displacement of the greater and lesser multangular bones (trapezium and trapezoid) sometimes accompanies this injury.

THE HAND.

Bony Landmarks.—The **First Metacarpal** does not lie in the same plane as the other metacarpal bones, but occupies a more anterior position. In addition, it is rotated medially through approximately 90° so that its extensor surface is directed laterally instead of dorsally. On this account the movements of the thumb occur in planes at right angles to the planes of the corresponding movements of the fingers (p. 84). The base of the **First Metacarpal** is readily felt in the angle between the tendons of the extensor pollicis brevis and longus, and the dorsal surface of its shaft can also be felt, though it is somewhat obscured by the extensor tendons.

In *Bennett's Fracture*, which passes obliquely through the base of the first metacarpal, the large, distal fragment is drawn proximally and slightly backwards by the combined action of the flexors and extensors of the thumb. The small, proximal fragment, which generally includes a part of the ulnar side of the shaft, suffers little displacement. Abnormal movement and crepitus are difficult to obtain, as it is not easy to fix the proximal fragment, owing to its small size. This fracture was difficult to recognise before the introduction of X-rays and was frequently mistaken for a sprain of the carpo-metacarpal joint.

The whole of the radial border and most of the dorsal surface of the **Second Metacarpal** can be readily examined ; its enlarged base forms a prominence on the back of the hand.

The dorsal surfaces of the **Third**, **Fourth**, and **Fifth Metacarpals** are obscured by the extensor tendons, but the **Styloid Process** on the base of the third can be felt about two fingers' breadths directly distal to the dorsal radial tubercle (p. 66) ; the tendon of the extensor carpi radialis brevis is attached to it. On the ulnar border of the hand, the tendon of the extensor carpi ulnaris can be traced to its insertion into the base of the fifth metacarpal.

Fractures of the metacarpal bones, when produced by direct violence, are transverse and show little displacement. When they follow indirect violence, they tend to be oblique, and the distal fragment is generally displaced proximally and backwards, causing a slight shortening of the corresponding finger.

The prominences of the **knuckles** are produced by the **heads of the metacarpal bones.** The dorsal groove corresponding to each *metacarpo-phalangeal joint* lies one-third of an inch distal to the head of each metacarpal. On the palmar aspect the joint corresponds to the lower skin crease of the palm and lies three-quarters of an inch from the edge of the web of the fingers.

The dorsal line of each *proximal inter-phalangeal joint* lies one-sixth of an inch distal to the prominence of the head of the first phalanx, and corresponds, on the palmar aspect, to the most proximal skin crease at the joint. The dorsal line of each *distal inter-phalangeal joint* lies one-twelfth of an inch distal to the prominence formed by the head of the second phalanx and corresponds, on the palmar surface, to the most distal skin crease at the joint.

The **Superficial Fascia** of the palm is rendered extremely tough by the presence of numerous fibrous septa, which connect the deep surface of the skin to the palmar aponeurosis (deep palmar fascia). On this account pus does not accumulate in any quantity in this situation, but makes its way through the cutis vera and collects under the epidermis as a purulent blister. Over the terminal phalanges the superficial fascia forms fatty pads, which are connected to the periosteum by fibrous septa. Superficial septic infection in this region, unless freely incised at an early stage, is apt to spread along the septa and cause suppurative periostitis. Ultimately, necrosis of the phalanx occurs, although sometimes the base of the bone, with the attachment of the flexor profundus tendon, is left behind.

On the *dorsum of the hand* the superficial fascia is thin and membranous. It contains most of the lymph vessels of the fingers and an irregular venous network, which gives rise to the basilic, median, and cephalic veins.

Superficial Vessels and Nerves.—The skin of the palm is supplied, as far as the heads of the metacarpals, by *palmar cutaneous branches* from the ulnar, median, and radial nerves. The *digital vessels* (p. 86) and the *digital nerves* (p. 86), which lie anterior to them, are situated in the superficial fascia on the sides of the fingers, nearer the palmar than the dorsal surface.

The skin on the dorsum is supplied by the terminal part of the *superficial* (*radial*) *branch of the radial* (*musculo-spiral*) *nerve* (p. 71) and by the *dorsal cutaneous branch of the ulnar* (p. 71).

Lymph Vessels.—All the superficial lymph vessels of the fingers and palm, save those of the proximal part which run up the front of the forearm, pass to the dorsum of the hand, and become associated with the superficial veins. They are joined by the deep lymph vessels of the palm, which reach the dorsum by passing across the distal border of the transverse head of the adductor pollicis. This arrangement explains the frequency with which œdema or even metastatic abscesses may occur on the dorsum of the hand, following septic infection of the fingers or palm.

Deep Fascia.—The deep fascia of the forearm fuses below with the palmar surface of the **Transverse Carpal (Anterior Annular) Ligament**, which is a strong fibrous band, situated in the proximal part of the hand. It provides a retentive apparatus for the flexor tendons, and is attached to the pisiform, and the hook of the hamate (unciform) on the ulnar side, and to the navicular tubercle and the ridge of the greater multangular bone (trapezium) on the radial side. A short band of fibres passes from the pisiform to fuse with the palmar surface of the ligament and, under cover of it, the ulnar nerve and artery are continued into the palm.

The deep fascia of the palm, which is termed the **palmar aponeurosis**, consists of a strong central portion, and two weak expansions which cover the muscles of the thenar and hypothenar eminences respectively. The central portion is exceedingly dense, and prevents the forward spread of pus or blood.

Proximally, it blends with the transverse carpal ligament; distally, it widens out and breaks up into four slips, which become continuous with the fibrous digital sheaths.

On the palmar aspect of the fingers, the deep fascia is attached to the borders of the phalanges and to the inter-phalangeal ligaments. On the terminal phalanx it is attached to the palmar surface of the bone immediately beyond the insertion of the tendon of the flexor digitorum profundus. In this way it forms a *fibrous sheath* for the flexor tendons, which lie in an osteo-fascial canal on the front of each finger. The sheath is thinner and weaker opposite the inter-phalangeal joints, to allow of free flexion (Fig. 29).

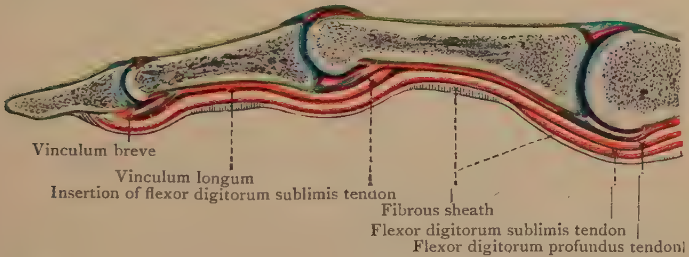

Vinculum breve
Vinculum longum
Insertion of flexor digitorum sublimis tendon
Fibrous sheath
Flexor digitorum sublimis tendon
Flexor digitorum profundus tendon

FIG. 29.—Longitudinal Section through the Third Finger, to show the arrangement of the Fibrous and Synovial Sheaths.

Light blue = articular cartilage. Green = periosteum.
Dark blue = ligaments. Red = synovial membrane.

In the early stages of **Dupuytren's Contraction** the metacarpo-phalangeal joints, generally of the ring and little fingers, become flexed, owing to an interstitial fibrosis of the medial part of the central portion of the palmar aponeurosis. Later, the inter-phalangeal joints also become flexed, as the fibrosis attacks the weak areas which are present in the fibrous digital sheaths opposite the joints.

In **Congenital Contraction of the Fingers**, which also affects the ring and little fingers, the metacarpo-phalangeal joints are hyperextended and the inter-phalangeal joints are flexed. This contraction, therefore, is not caused by the action of the aponeurosis, but is suggestive of some functional incapacity of the lumbricals supplied by the ulnar nerve (p. 84).

The **Hypothenar Eminence** is produced by the *abductor*, the *opponens*, and the *flexor digiti quinti brevis*. These muscles are all supplied by the deep branch of the ulnar nerve (C. 8 and T. 1), and their actions are sufficiently described by their names. *When pus forms in the hypothenar eminence*, it is localised to that area, as it is shut off from the central portion of the palm by a *fibrous septum*, which passes backwards from the ulnar side of the central portion of the palmar aponeurosis. In these cases the *incision* is made over the ulnar side of the fifth metacarpal bone, dorsal to the pisiform. The nerves of supply, which enter the muscles close to the pisiform, are not interfered with by this incision, and no damage is done to the first digital branches of the superficial volar arch and ulnar nerve, which run distally, in front of the flexor digiti quinti brevis, to supply the ulnar side of the little finger.

The **Thenar Eminence** is formed by the *abductor pollicis*, the *flexor pollicis brevis*, and the *opponens pollicis*, which lies deep to the preceding two muscles. These three muscles lie to the radial side of the tendon of the flexor pollicis longus, and are all supplied by the median nerve (C. 8 and T. 1). They are shut off from the central space of the palm by a *fibrous septum*, which passes backwards from the radial border of the central portion of the palmar aponeurosis. *When pus forms amongst these muscles*, it is very definitely localised, and shows no tendency to spread backwards or medially. The *incision* lies over the distal part of the first metacarpal and on the radial side of the eminence, thus avoiding the nerves of supply, which enter the muscles at their carpal ends, and the digital nerve to the radial side of the thumb (Fig. 30).

Movements of the Thumb.—Flexion and extension are the only movements which occur at the metacarpo-phalangeal and inter-phalangeal joints of the thumb. The additional movements of abduction, adduction, and opposition all take place at the carpo-metacarpal joint, where the os multangulum majus (trapezium) articulates with the first metacarpal bone. This joint possesses a special synovial membrane, distinct from the synovial membrane of the neighbouring joints. *Abduction and adduction occur in an antero-posterior plane*, and the former movement must not be confused with true extension, which occurs in a medio-lateral plane.

The Central Portion of the Palm.—The tendons of the flexor digitorum sublimis and profundus lie behind the central portion of the palmar aponeurosis before they enter the fibrous digital sheaths. Opposite the first phalanx each sublimis tendon splits, to allow the corresponding profundus tendon to pass on to be inserted into the base of the distal phalanx. Under cover of the profundus tendon the two slips of the sublimis tendon receive attachment to the borders of the second phalanx.

The four **Lumbrical Muscles** arise from the tendons of the flexor digitorum profundus in the palm, and are inserted into the radial side of the dorsal extensor expansion (p. 92) and the adjoining part of the first phalanx of the medial four digits. They flex the fingers at the metacarpo-phalangeal joints, but extend them at the inter-phalangeal joints, through the medium of the extensor expansion. The lumbricals of the little and ring fingers are supplied by the deep branch of the ulnar nerve (C. 8 and T. 1); those of the middle and index fingers, by the median nerve (C. 8 and T. 1).

It should be noted that the extensor digitorum communis acts only on the proximal phalanges, and that extension of the fingers at the interphalangeal joints is carried out by the lumbricals and the interossei (p. 90).

The **Ulnar Nerve** divides into *superficial* and *deep branches* opposite the hook of the hamate bone. The former supplies digital branches to the little finger and to the ulnar side of the ring finger. The latter supplies the muscles of the hypothenar eminence and runs transversely across the palm to end in the oblique head of the adductor pollicis. In its course it accompanies the deep volar arch (p. 92), and lies behind the flexor tendons and in front of the interossei and the proximal ends of the middle three metacarpals. In addition to the muscles already mentioned, it supplies all the interossei, the transverse head of the adductor pollicis, and the medial two lumbricals.

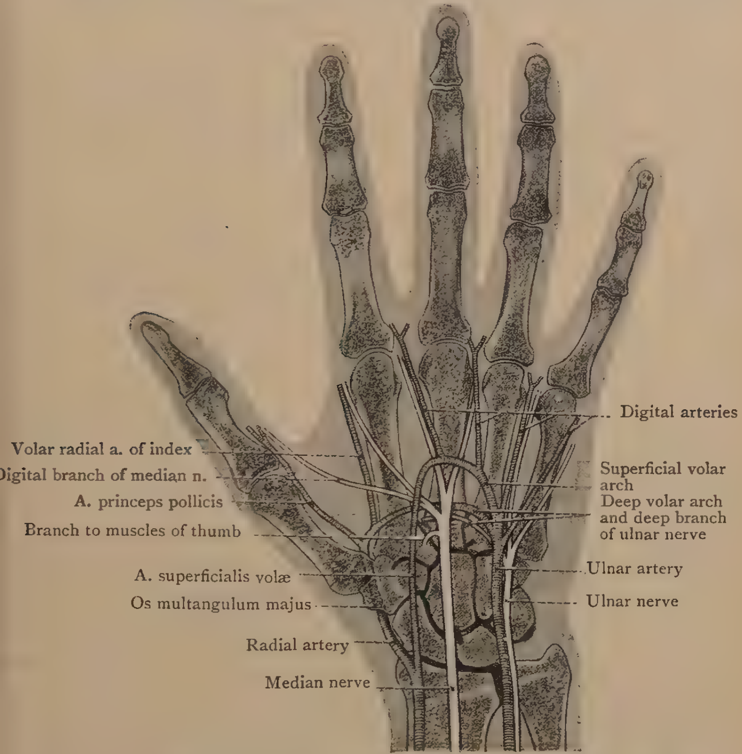

Digital arteries
Volar radial a. of index
Digital branch of median n.
A. princeps pollicis
Branch to muscles of thumb
Superficial volar arch
Deep volar arch and deep branch of ulnar nerve
Ulnar artery
Ulnar nerve
A. superficialis volæ
Os multangulum majus
Radial artery
Median nerve

FIG. 30.—The Positions of the Vessels and Nerves Relative to the Bones of the Hand and Wrist.

The **Median Nerve** enters the palm behind the transverse carpal (anterior annular) ligament. At the lower border of the ligament it breaks up into lateral and medial divisions. The *lateral division* at once supplies the thenar muscles (p. 84) and gives off digital branches to supply both sides of the thumb and the radial side of the index finger. The *medial division* gives off two branches, which run to the second and third clefts to supply the adjacent sides of the index, middle, and ring fingers, and twigs to their dorsal aspects (p. 72). The digital branches of the radial side of the index finger and the second cleft supply the first and second lumbricals respectively.

The **Superficial Volar (Palmar) Arch** is the continuation of the ulnar artery into the palm. It runs obliquely, distally, and laterally across the hook of the hamate to reach the mid-point between the base of the middle finger and the distal skin crease at the wrist. The mode of termination of the arch is very variable, but it is always joined by a branch from the radial artery (superficialis volæ, princeps pollicis or radialis indicis), and the anastomosis is so free that in wounds of the arch both the cut ends require to be tied. The artery lies immediately under cover of the central part of the palmar aponeurosis, and it crosses in front of the flexor tendons and their sheaths and the digital branches of the median nerve.

It gives off four *Digital Branches*. The first supplies the ulnar side of the little finger (p. 84); the second passes to the fourth cleft, and lies to the ulnar side of the fourth metacarpal bone; the third passes to the third cleft and lies to the radial side of the same bone; the fourth crosses the third metacarpal bone to gain the second cleft. *An incision can therefore be made over the distal part of the fourth metacarpal bone, without injuring the superficial volar arch or any of its digital branches* (Fig. 30).

Synovial Sheaths of the Flexor Tendons.—As the flexor tendons pass into the palm, they are invested with synovial sheaths, which are arranged in a somewhat complicated manner.

The tendon of the flexor pollicis longus has a separate sheath, which extends distally as far as its insertion and proximally for an inch or more beyond the transverse carpal ligament. It consists of a "*visceral*" *layer*, closely applied to the tendon, and a *parietal layer*, which lines the walls of the space occupied by the tendon. At both extremities of the sheath the parietal layer is reflected on to the tendon to become continuous with the "visceral" layer, so that the two enclose an elongated bursal space.

It is as if the tendon were invaginated into the synovial bursa from behind, and at first possessed a "mesentery" throughout its whole extent in the sheath. This complete "mesentery" breaks down in places, but it persists as the *ligamentum breve,* a triangular fold attaching the terminal part of the tendon to the floor of its canal, and as the *ligamenta longa,* which connect it to the floor in two or three places at a more proximal level (Fig. 29).

The tendons of the flexor digitorum sublimis and profundus are provided with a single large sheath (*the common palmar sheath*), which extends proximally as far as that of the flexor pollicis longus. Its distal limit is oblique, reaching a more distal level on the ulnar than on the radial side. The most medial part of the sheath is carried distally on the tendons of the little finger to their insertions (Fig. 32).

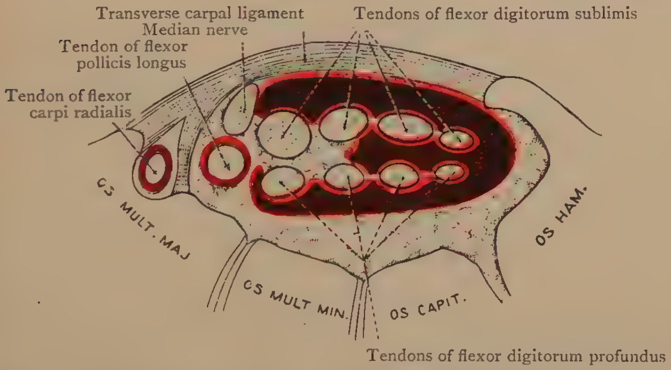

Transverse carpal ligament
Median nerve
Tendon of flexor pollicis longus
Tendon of flexor carpi radialis
Tendons of flexor digitorum sublimis
OS MULT. MAJ.
OS MULT. MIN.
OS CAPIT.
OS HAM.
Tendons of flexor digitorum profundus

FIG. 31.—Diagram of a Transverse Section through the Carpus, to show the arrangement of the Synovial Sheaths.

Figure 31 represents a transverse section through the wrist at the level of the transverse carpal ligament. From this it will be seen that the tendons have been invaginated into the common palmar sheath on its radial side, and have formed three pouches—one in front of the sublimis, *pre-tendinous pouch*; one between the two groups of tendons, *inter-tendinous pouch*; and a third, between the profundus and the floor of the carpal tunnel, *retro-tendinous pouch*. The open space at the ulnar side of the sheath, with which all three pouches communicate freely, is termed the *ulnar bursa.*

The median nerve is situated between the sheath of the flexor pollicis longus and the common palmar sheath.

Digital Synovial Sheaths invest the flexor tendons as they lie in their osteo-fascial canals on the front of the fingers. They extend distally as far as the insertion of the profundus tendons, and proximally for half an inch beyond the metacarpo-phalangeal joints. *Ligamenta longa* and *brevia* are present as in the case of the flexor pollicis longus (Fig. 29). The digital synovial sheath of the little finger is directly continuous with the common palmar sheath, but the others are definitely closed at their proximal ends.

The following variations are described by Poirier.

1. The index tendon of the profundus possesses a separate palmar sheath, 80 per cent.
2. The flexor pollicis longus sheath communicates freely at its proximal part with the common sheath, 50 per cent.
3. The digital sheath of the little finger fails to communicate with the common sheath, 35 per cent.
4. The flexor pollicis longus sheath is in two separate parts, a digital and a carpal, 5 per cent.

Pus in the Common Palmar Sheath. — The common palmar sheath may be infected primarily by punctured wounds of the palm or it may be involved secondarily, following a septic infection either of the digital synovial sheath of the little finger (Fig. 32) or of the middle palmar space (p. 90). *Incisions into the proximal part of the sheath* are made in the line of the ring finger, and are limited distally by the distal skin crease at the wrist. In this way no damage is done to the median nerve which lies to the radial side of the incision or to the ulnar nerve and artery, which lie to its medial side. *Incisions into the distal part of the sheath* are made in the same line, but are limited proximally by the distal border of the transverse carpal ligament and distally by the superficial palmar arch. If the pus ruptures the common palmar sheath and extends into the forearm, it may be evacuated by incisions along the same line (Fig. 32).

Compound Palmar Ganglion.—This condition is a tuberculous synovitis affecting the common palmar sheath. It gives rise to a dumb-bell-shaped swelling, which extends from the distal part of the forearm into the palm, the constriction being due to the transverse carpal ligament. Should a cold abscess arise, the common palmar sheath may require to be excised,

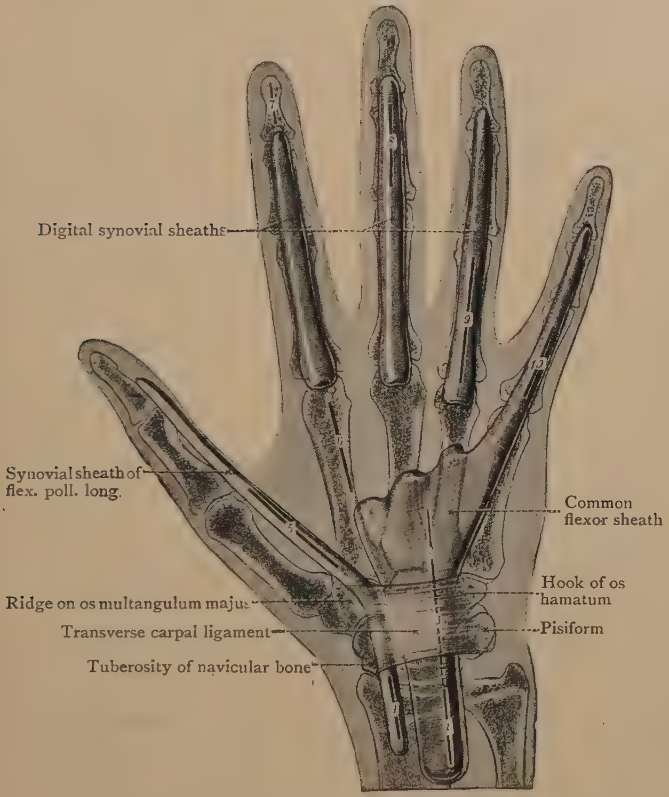

Digital synovial sheaths
7
8
9
10
Synovial sheath of flex. poll. long.
6
5
Common flexor sheath
Hook of os hamatum
Ridge on os multangulum majus
Transverse carpal ligament
Pisiform
Tuberosity of navicular bone
3
1

FIG. 32.—The Synovial Sheaths of the Wrist and Hand. The positions of various incisions for the evacuation of pus are also shown.

1 and 2. Incisions into the common palmar sheath, placed between the median and ulnar nerves.
3. Incision uniting 1 and 2.
4. Incision into the proximal part of the sheath of flexor pollicis longus. It is placed between the radial artery and the median nerve.
5. Incision into the distal part of the sheath of flexor pollicis longus.
6. Incision into the thenar space.
7. Incision over terminal phalanx.
8, 9 and 10. Incisions into the digital sheaths. They lie opposite the shafts of the phalanges.

though the operation usually results in some damage to the median and ulnar nerves.

Deep Muscles of the Palm.—The *adductor pollicis* possesses a *transverse* and an *oblique* head, which are both supplied by the deep branch of the ulnar nerve (C. 8). It forms a triangular sheet of muscle, with its base attached to the third metacarpal bone and its apex to the base of the first phalanx of the thumb. In the interval between the two heads the radial artery enters the palm.

The three *volar* (*palmar*) *interossei*, which arise from the metacarpal bones of the fingers on which they act, adduct the little, ring, and index fingers to the middle line of the hand. The four *dorsal interossei* abduct the ring, middle, and index fingers from the same line. Both groups are supplied by the deep branch of the ulnar nerve (C. 8 and T. 1), and, in addition to the above actions, they help the lumbricals to flex the fingers at the metacarpo-phalangeal joints and, by virtue of their partial insertion into the dorsal extensor expansion, to extend them at the inter-phalangeal joints.

Fascial Spaces of the Palm. — Behind the flexor tendons and the lumbrical muscles, there exists a large fascial space, which is subdivided into a *Middle Palmar* and a *Thenar Space* by a septum of fibrous tissue attached to the third metacarpal bone (Kanavel). This septum is weakened at its proximal end, but it is usually strong enough to prevent the spread of pus from the one space to the other.

The **Middle Palmar Space** lies to the radial side of the hypothenar eminence, from which it is completely separated by a fascial septum (p. 84). It is bounded behind by the strong fascia which covers the interosseous muscles in the third and fourth spaces, and in front by the tendons of the middle, ring, and little fingers with their lumbrical muscles. This fascial space may be *primarily* infected by punctured wounds or by compound fractures of the third, fourth, and fifth metacarpals. It can be involved *secondarily* to superficial infections of the same fingers, the spread occurring along the sheath of the lumbrical muscle ; or it may be involved by direct spread from the digital synovial sheaths of the third and fourth fingers, the pus rupturing through the closed proximal end of the sheath. If not evacuated, pus in the middle palmar space may spread distally to point at the web of the fingers ; or it may spread proximally behind the tendons into the forearm ; or, in neglected cases, it may pass backwards between the metacarpal bones and infect the dorsal subaponeurotic space (p. 91). *Incisions into the space* are made over the distal half of the fourth metacarpal bone (p. 86), and the tendons of the ring finger are exposed at a point where they have no synovial sheath. In this way the middle palmar space can be reached without opening into the common palmar sheath, which is not necessarily infected.

The **Thenar space** lies between the middle palmar space and the tendon of the flexor pollicis longus. It is bounded behind by the adductor of the thumb and in front by the tendons of the index finger and the first lumbrical muscle. *Primary infections* of this space may occur through punctured wounds, and, very rarely, through compound fracture of the second metacarpal, which is separated from it by the adductor muscle of the thumb. Septic infections of the index finger may involve the space *secondarily*, following the same routes as have been described above in connection with the middle palmar space. Pus in the thenar space may spread backwards between the two heads of the adductor muscle, or over the distal border of the transverse head to point on the dorsal surface of the web of the thumb. It may also pass proximally into the forearm or distally to the interval between the index and middle fingers. *Incisions into the thenar space* are made over the distal half of the second metacarpal (Fig. 32), and " through and through " drainage may be obtained in the space between the first and second metacarpal bones.

The **Dorsal Carpal (Posterior Annular) Ligament** is a thickened portion of the deep fascia on the back of the wrist. It is attached to the volar (anterior) border and styloid process of the radius, and it passes obliquely across the dorsum of the wrist, to be attached to the styloid process of the ulna and the medial border of the carpus. Septa unite its deep surface to the dorsal aspect of the radius, and form complete osteo-fascial tunnels for the extensor tendons.

Synovial Sheaths of Extensor Tendons.—Synovial sheaths invest the extensor tendons as they lie under cover of the dorsal carpal ligament. They extend for a short distance proximal to the ligament and distally for an inch or more beyond it. Six sheaths are present at the back of the wrist, and they surround the tendons of :—

1. Abductor pollicis longus (Ext. oss. metacarp) and Ext. pollicis brevis.
2. Ext. carpi radialis longus and brevis.
3. Ext. pollicis longus. At the point where this tendon crosses the radial extensors of the wrist, the two synovial sheaths communicate freely.
4. Ext. digitorum communis and indicis proprius.
5. Ext. digiti quinti proprius.
6. Ext. carpi ulnaris.

The characteristic " new leather creaking " of teno-synovitis in this region is due to friction between the inflamed " visceral " and parietal layers of the tendon sheaths. The tendons of the radial extensors are most commonly affected.

Carpal Ganglion, which usually occurs in relation to the tendons of the radial extensors of the wrist, may or may not be continuous with their sheaths. According to some authorities it may arise from a degeneration of the ligaments in this region or from the bursæ which are situated immediately beneath the insertions of these tendons.

The Dorsal Subaponeurotic Space.—On the dorsum of the hand the extensor tendons of the fingers are united to one another by oblique bands in such a way as to form with the deep fascia an aponeurotic sheet, which is attached, on each side, to the borders of the second and fifth metacarpals. The dorsal subaponeurotic space (Kanavel) lies between this sheet and the dorsal surfaces of the medial four metacarpals and interosseous muscles. Septic infection of the space is generally *primary*, following wounds on the dorsum. It may be involved *secondarily* to infections of the middle palmar space (p. 90), but it is never infected from the thenar space (p. 90). When pus collects in this situation it is limited distally at the metacarpo-phalangeal joints and proximally, at the bases of the metacarpal bones, by fibrous partitions. On each side it is limited opposite the borders of the second and fifth metacarpal bones. *Incisions through the aponeurosis* are made between the tendons distally and run transversely, so that they may be kept open by the traction of the extensor tendons, thus ensuring good drainage.

In infections of the middle palmar space, "through and through" drainage is obtained through the fourth interosseous space and the dorsal aponeurosis.

Insertion of the Digital Extensor Tendons.—The tendons of the extensor digitorum communis form a strong expansion on the dorsum of the knuckles and first phalanx, which fuses with the dorsal surface of the capsule of the metacarpo-phalangeal joint. Into this expansion are inserted the tendons of the lumbricals and interossei. On the index and the little fingers the expansion is strengthened by the tendons of the extensor indicis and quinti digiti proprius, which blend with it. The central portion of the expansion is inserted into the base of the second phalanx, while the collateral portions pass to the terminal phalanx.

When pus collects under the dorsal expansion it cannot spread on to the dorsum of the hand until it has infected the metacarpo-phalangeal joint.

Radial Artery.—On leaving the forearm the radial artery winds round the radial side of the wrist lying on the radial collateral ligament. It crosses the dorsal surface of the navicular and the os multangulum majus (trapezium), and then passes forwards into the palm at the proximal end of the first interosseous space to form the *deep volar arch* (Fig. 30).

The radial artery appears in the palm between the transverse and the oblique heads of the adductor pollicis, and forms the deep volar arch by joining the deep branch of the ulnar artery. The arch lies deep to the flexor tendons and their synovial sheaths, and, if hæmorrhage from it cannot be controlled by pressure, etc., recourse is usually had to ligature of the ulnar and radial arteries. In this case the circulation is gradually re-established through the volar and dorsal interosseous arteries (p. 71).

The deep arch, which lies one finger's-breadth proximal to the superficial arch, sends branches proximally to join the volar carpal arch, and distally to join the digital arteries.

Incisions on the Fingers.—Incisions on the palmar aspect of the fingers are made in the middle line to avoid injuring the digital vessels and nerves.

Incisions on the dorsal aspect of the first phalanx should be confined, if possible, to the ulnar side to avoid injuring the attachment of the lumbrical muscle (p. 84). In the case of the second phalanx, dorsal incisions may be made to either side of the extensor tendon. Septic infection on the dorsal surface of the terminal phalanx is usually of the nature of an onychia and involves the nail bed. It may spread to the bone unless full exit is given to the pus by removal of the nail.

Ossification of the Metacarpals and Phalanges. — The shafts and distal extremities of the phalanges ossify from primary centres; the proximal extremities from separate epiphyses, which ossify during the third year and unite with the shafts at twenty. The metacarpal bone of the thumb ossifies in the same way as a phalanx, but in the other metacarpal bones the bases and shafts are derived from the same primary centres, while the heads are formed by separate epiphyses, ossifying at three and uniting with the diaphyses at twenty.

Tuberculous Dactylitis usually attacks the centres of the shafts of the metacarpals and phalanges instead of their extremities, probably because the nutrient artery on entering the bone at once breaks up into small branches, whereas in the other long bones it divides into large ascending and descending branches. Owing to their mode of ossification, the diaphyses of these bones cannot be completely resected subperiosteally without opening one of the joints. On this account, after the periosteum has been elevated, the bone is divided close to the extremity which has no epiphysis. The diaphysis can then be lifted and broken away from the epiphyseal cartilage at the opposite extremity.

The **Metacarpo-Phalangeal Joints** possess volar and collateral ligaments, but the dorsal ligament is replaced by the extensor expansion. The *volar accessory* (*glenoid*) *ligament* is a plate of fibrocartilage, which is firmly attached to the proximal phalanx but only feebly connected with the metacarpal bone.

Dorsal Dislocation of the Thumb, at its metacarpo-phalangeal joint (Hey's dislocation), is produced by extreme dorsi-flexion of the thumb. The volar accessory ligament gives way at its weak proximal attachment, and the phalanx passes backwards, carrying the ligament with it. The distal phalanx is flexed by the flexor pollicis longus. Hyper-extension at the metacarpo-phalangeal joint is primarily due to the causative

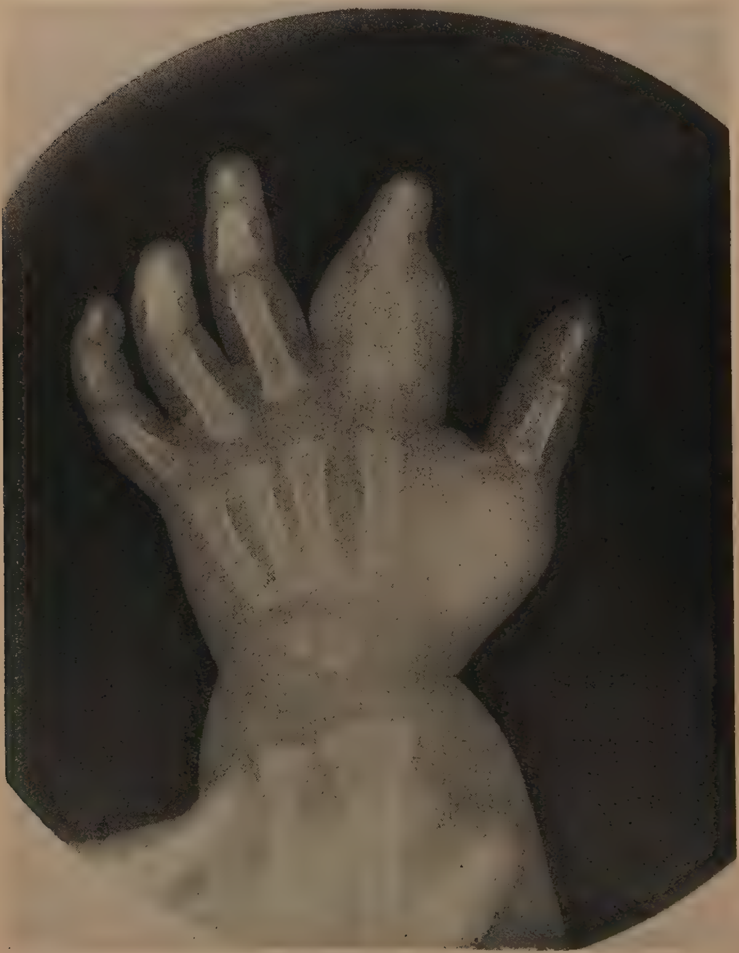


FIG. 33.—The Hand of a Child of three, showing Tuberculous Dactylitis. The first metacarpal and the proximal phalanx of the index finger are affected by the disease. Note the stage of ossification of the carpus and metacarpus.

force, and is maintained by the abductor pollicis brevis, whose "line of pull" falls behind the point of contact of the phalanx with the head of the metacarpal. As soon as manipulations have succeeded in bringing the line of pull in front of the point of contact, hyper-extension is replaced by a slight degree of flexion.

Difficulty in reduction may be caused (1) by the head of the metacarpal being caught between the flexor pollicis brevis and the adductor pollicis, (2) by the tendon of the flexor pollicis longus slipping over to the ulnar side of the metacarpal, or (3) by the interposition of the volar accessory ligament between the two bones. Reduction is brought about by traction and hyper-extension in order to allow the torn end of the volar ligament to pass over the head of the metacarpal before the thumb is flexed to the palm.

Development of Fingers.—During the sixth week of fœtal life, four linear furrows appear on the distal part of the upper limb. These deepen and finally become clefts, which separate the digits from one another. The furrows may be incomplete, giving rise to webbing of the fingers (*syndactylism*); or extra furrows may develop and produce supernumerary digits (*polydactylism*). In the former case the furrow may be so shallow that the bones of contiguous digits are fused together.

THE BRACHIAL PLEXUS AND ITS BRANCHES.

The brachial plexus is formed by the anterior rami (anterior primary divisions) of the lower four cervical and the first thoracic nerves, assisted by small twigs from the fourth cervical and the second thoracic nerves. The twig from the fourth cervical joins the fifth, which then unites with the sixth, constituting the **Upper Trunk** of the Plexus. The seventh cervical alone forms the **Middle Trunk.** The eighth cervical and the first thoracic unite to form the **Lower Trunk.** Each of these trunks divides into an anterior and a posterior branch, and the three posterior branches join to form the **Posterior Cord** of the Plexus. The anterior branches of the upper and middle trunks join to form the **Lateral Cord,** while the anterior branch of the lower trunk forms the **Medial Cord** (Fig. 34).

Supra-clavicular Branches.

Long Thoracic Nerve (of Bell), C. 5, 6, and 7.
Dorsalis Scapulæ (Nerve to Rhomboids), C. 5.
Nerve to Subclavius, C. 5 and 6.
Supra-scapular, C. 5 and 6.

Infra-clavicular Branches.

Lateral Cord
- Lateral Anterior Thoracic (C. 5, 6, and 7).
- Lateral Head of Median (C. 5, 6, and 7).
- Musculo-Cutaneous (C. 5, 6, and 7).

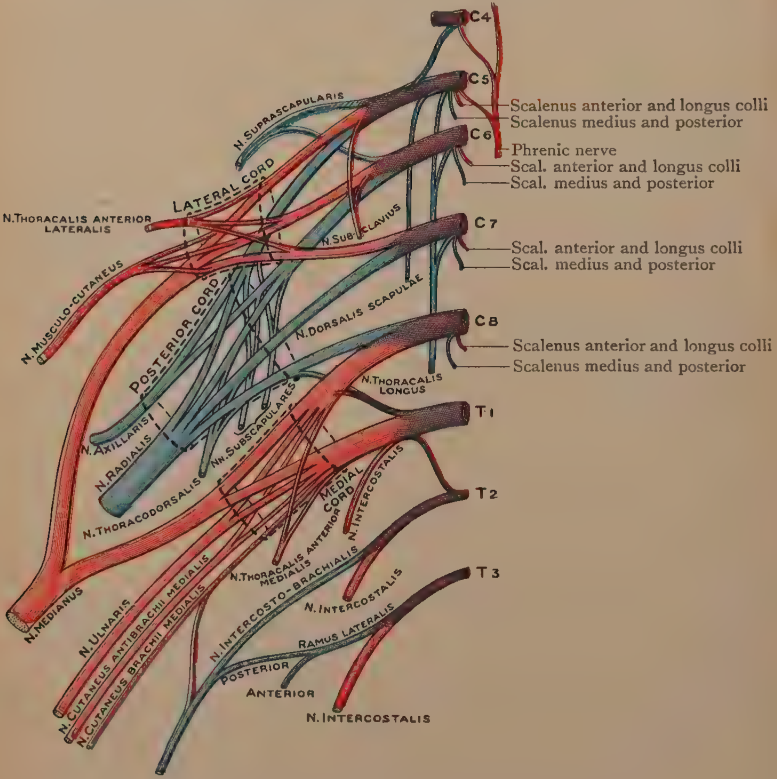

C4
C5
Scalenus anterior and longus colli
Scalenus medius and posterior
C6
Phrenic nerve
Scal. anterior and longus colli
Scal. medius and posterior
C7
Scal. anterior and longus colli
Scal. medius and posterior
C8
Scalenus anterior and longus colli
Scalenus medius and posterior
T1
T2
T3
N. Suprascapularis
Lateral Cord
N. Thoracalis anterior lateralis
N. Subclavius
N. Musculo-cutaneus
Posterior Cord
N. Dorsalis scapulae
N. Thoracalis longus
N. Axillaris
N. Radialis
Nn. Subscapulares
Medial Cord
N. Intercostalis
N. Thoracodorsalis
N. Thoracalis anterior medialis
N. Intercosto-brachialis
N. Medianus
N. Ulnaris
N. Cutaneus antibrachii medialis
N. Cutaneus brachii medialis
N. Intercostalis
Ramus lateralis
Posterior
Anterior
N. Intercostalis

FIG. 34.—Diagram of Brachial Plexus. (After Paterson.)

Medial Cord
- Medial Anterior Thoracic (C. 8 and T. 1).
- Medial Cutaneous of Arm (Lesser Internal Cutaneous) (T. 1).
- Medial Cutaneous of Forearm (Internal Cutaneous) (C. 8 and T. 1).
- Medial Head of Median (C. 8 and T. 1).
- Ulnar (C. 8 and T. 1).

Posterior Cord
- Upper (Short) Subscapular (C. 5 and 6).
- Lower (Middle) Subscapular (C. 5 and 6).
- Thoraco-dorsal (Long Subscapular) (C. 6, 7, and 8).
- Radial (Musculo-Spiral) (C. 5, 6, 7, and 8).
- Axillary (Circumflex) (C. 5 and 6).

Lesions of the plexus or of its constituent parts are followed by alterations in the motor and sensory functions in the area supplied. It must be remembered that the areas supplied by cutaneous nerves overlap one another to a considerable extent, and that section of a single cutaneous nerve will produce an area of altered sensibility which is much smaller than the area of anatomical supply of the nerve involved.

Two principal varieties of sensibility are generally recognised, viz. (*a*) cutaneous and (*b*) deep sensibility. *Cutaneous sensibility* has been shown (Head and Sherren) to comprise two components (1) epicritic and (2) protopathic sensibility, both of which are conveyed by the cutaneous nerves. The former responds to light touch, localises accurately all painful and tactile stimuli, and recognises slight differences of temperature. It requires the cerebral cortex (post-central gyrus) for its interpretation. *Protopathic sensibility*, which responds to coarser stimuli, recognises but does not localise painful stimuli, and appreciates only the extremes of hot and cold. This variety of sensibility is retained after destruction of the post-central gyrus and requires only the thalamus for its interpretation.

Deep sensibility responds to pressure and postural stimuli. According to Head, all the fibres conveying deep sensibility run with the motor nerves and associate themselves with muscles, tendons, ligaments and periosteum. According to Stopford, deep sensibility can be analysed into two components. The one corresponds to the epicritic component of cutaneous sensibility, since it is concerned with the localisation of pressure stimuli and the recognition of joint posture, and since it requires the cortex for its interpretation. These fibres travel with the cutaneous nerves and are given off by them to the subcutaneous tissues, including the joints. The other component corresponds to the protopathic component of cutaneous sensibility, since it responds to coarser stimuli, viz. pressure pain and pressure, and requires only the thalamus for its interpretation.

In the regeneration of a peripheral nerve after suture, the proximal ends of the cut nerve fibres grow down into the distal end of the nerve. The growing fibres enter the distal cut ends of the nerve sheaths and so are conducted to their destination. The resultant degree of recovery will depend on the number of fibres which succeed in establishing connections with nerve sheaths which previously contained fibres of the same type. It will be clear, therefore, that the power of localisation of tactile, painful and thermal stimuli is the least likely to recover, whereas protopathic sensibility is much more likely to do so, since recovery will take place if a protopathic "pain" (or "temperature") fibre grows down the sheath of a protopathic "pain" (or "temperature") fibre, whether it be its own original sheath or not. In the same way, the coarser component in deep sensibility is more likely to recover than the finer component (Stopford).

Nerve Injuries.—Three main groups of nerve injuries are recognised, namely: (*a*) lesions involving Interruption; (*b*) lesions involving Compression; and (*c*) lesions involving Irritation.

In (*a*) the **Interruption** may be due to complete division of all the constituent fibres of the nerve, or to compression (usually by scar tissue) of so serious a nature that conductivity is completely interfered with and the distal portions of the fibres undergo Wallerian degeneration. Injuries of this type are characterised by (1) complete paralysis of the muscles innervated by the injured nerve distal to the lesion, together with loss of tone and progressive atrophy; (2) the Reaction of Degeneration; (3) extensive sensory changes, corresponding (more or less accurately, according to the degree of overlapping by adjoining nerves) to the distribution of the injured nerve. It should be remembered that the loss of cutaneous sensibility is always greater than the loss of deep sensibility in interruptive lesions. Certain negative characteristics are important. (1) Trophic disturbances are either entirely absent or represented by slight œdema and cyanosis of the skin. (2) There is complete absence of subjective pain, and no painful sensations are aroused by pressure over the nerve or on the paralysed muscles.

(*b*) The second group of injuries, those due to **Compression**, is comparatively uncommon. It is typically seen in "Crutch Palsy" of the radial (musculo-spiral) nerve. Complete, or almost complete, loss of conductivity occurs, but it is never accompanied by Wallerian degeneration, *i.e.* there is no true destruction of nerve fibres. As in interruptive lesions, there is complete motor paralysis, but the sensory loss is not so extensive, and is liable to variation. According to Stopford, the area of protopathic loss is greater than the area of epicritic loss. When the cause is removed, recovery is rapid and usually complete.

(*c*) The third group of nerve injuries is characterised by symptoms and signs which result from **Irritation**. *The nerve is partially divided and is the site of peri- and intra-neural fibrosis.* The characteristic features of this group are Pain and Trophic disturbances.

The pain varies in character, but it is usually severe, and is increased by movements of the paralysed limb and by pressure on the nerve or on the paralysed muscles. It is frequently of an intense, burning character, and hence the condition is referred to as *Causalgia* or *Thermalgia*.

The skin is usually smooth, glossy and hyperæmic, and undergoes fibrous infiltration. The nails become in-curved, and alterations occur in the terminal phalanges.

The motor paralysis is incomplete, but such muscles as are paralysed show hypertonicity and increasing firmness due to fibrosis. The synovial sheaths may be partly obliterated by adhesions, and there may be contractures of the tendons and aponeuroses. The resulting deformities are irreducible, in marked contrast with the deformities found in interruptive lesions, where reduction is easy.

These three groups of nerve injuries differ from one another in their history as well as in the signs and symptoms which they produce. In interruptive lesions the condition shows no change after the first few weeks. In compression lesions progressive improvement follows removal of the cause. In irritative lesions the condition becomes more and more accentuated.

For a complete account of the physiology of the peripheral nerves and of the pathology of nerve injuries, the reader should consult the writings of the authors referred to above.

Hysterical Paralysis.—Anæsthesia and loss of motor power are frequently found in cases of hysteria. The paralysis is flaccid and the muscles affected do not correspond to those supplied by any particular nerve or nerves. The sensory loss is usually of the "glove" (or, in the case of the lower limb, "stocking") variety. It should be observed, however, that functional paralyses may exaggerate an existing organic lesion, especially of the irritation type, and care must be taken to determine the precise extent of the actual nerve injury.

Lesions of the Supra-clavicular Branches.—The **Long Thoracic Nerve (of Bell)** (C. 5, 6, and 7) and the **Dorsalis Scapulæ Nerve (to the Rhomboids)** (C. 5) both arise so close to the intervertebral foramina that they are rarely injured in tears of the plexus. The latter nerve may be injured in removal of lymph glands from behind the posterior belly of the omohyoid, unless the prevertebral fascia on the floor of the posterior triangle of the neck is left intact (p. 139). In *paralysis of the rhomboid muscles* the scapula on the injured side lies slightly lower than it should, and the inferior angle is at a greater distance from the median plane than it is on the sound side.

The **Long Thoracic Nerve (of Bell)** (p. 135) may be injured in operations involving the axilla (p. 35) or by the pressure of weights carried on the shoulder. In the latter case the dorsalis scapulæ nerve (to the rhomboids) and the branches of C. 3 and C. 4—both motor and sensory—which cross the posterior triangle of the neck (p. 129), may also be injured. Owing to this complication, paralysis of the serratus anterior (s. magnus) is frequently accompanied by paralysis of the lower part of the trapezius and by pain, which radiates over the distribution of C. 3 and C. 4. When the serratus anterior is paralysed alone, the patient is unable to raise the humerus above the level of the shoulder. If his arm is passively raised above that level, forward pushing movements cannot be performed, and attempts to produce them cause marked *winging of the scapula*. All the other movements, including forward pushing below the shoulder, are intact, and, although the latter is weaker, it does not produce winging of the scapula (Sherren). When in addition the lower fibres of the trapezius (C. 3 and 4) are affected, no forward pushing movement can be performed, and marked winging of the scapula results on its being attempted.

The **Supra-scapular Nerve** (p. 131) arises from the upper trunk of the plexus (C. 5 and 6) and supplies the supra- and the infra-spinatus. When it is injured alone—a rare occurrence—the resulting disability is slight, as lateral rotation of the humerus, though definitely weakened, can still be performed by the teres minor and the posterior fibres of the deltoid. In Erb-Duchenne paralysis (p. 101) the lesion usually occurs proximal to the origin of the supra-scapular nerve, which is therefore involved.

Lesions of the Brachial Plexus. — As the brachial plexus passes towards the axilla its constituent parts converge on one another at the outer border of the first rib, the upper having a downward and the lower an upward inclination. On this account violence applied to the shoulder in a downward direction will cause a stretching or tearing of the upper trunk (Erb-Duchenne type, p. 101), and violence applied in the opposite direction will affect the lower trunk in a similar manner (Klumpke type, p. 102).

Supra-clavicular lesions of the plexus are generally brought about as the result of trauma (*e.g.* in complicated labour, in artificial respiration, when a person falling from a height grasps something to save himself, or when the arm of an unconscious patient hangs unsupported over the edge of an operating table), but they may also occur from the pressure of a cervical rib.

Hæmorrhagic extravasation or effusion into a nerve trunk is quite sufficient to produce a temporary paralysis of the muscles supplied. Rapid and complete recovery differentiates this condition from an actual rupture of nerve fibres.

The **whole plexus may be injured**, but unless the nerves are torn close to the intervertebral foramina, the rhomboids and the serratus anterior escape. Sometimes all the trunks of the plexus are torn, and when this occurs distal to the origin of the supra-scapular nerve, the supra- and the infra-spinatus escape paralysis. The examination of these muscles and of the condition of the pupil (p. 128) helps to determine the site of all such extensive lesions.

In these injuries, epicritic and protopathic sensibility are lost over the whole arm, except in the areas supplied by the descending branches of the cervical plexus (C. 3 and 4) on the lateral side of the arm, and by the intercosto-brachial nerve on the medial side of the arm (Fig. 13). The full area of supply of these nerves is demonstrated as the overlapping nerves are all paralysed.

It is important to remember that limited hæmorrhage into the spinal medulla, from disease or accident, or the onset of acute anterior poliomyelitis may give rise to clinical signs similar to those produced by injuries of the plexus. It is necessary, therefore, to examine the lower limbs for signs of motor and sensory disturbance in order to determine whether the plexus or the spinal medulla is the site of the lesion.

Erb-Duchenne or Upper Arm Type of Paralysis.—This condition results usually from downward traction of the shoulder during complicated labour. The upper trunk is torn *proximal to the origin of the supra-scapular nerve, but distal to the origins of the long thoracic nerve (of Bell) and the dorsalis scapulæ nerve (to the rhomboids)*. The serratus anterior and the rhomboids consequently escape, but all the other muscles innervated by C. 5 and C. 6 are paralysed (p. 108). The deltoid, teres minor, and infra-spinatus are all affected, and the arm is rotated medially by the latissimus dorsi (C. 6, 7, and 8) and the sternal head of the pectoralis major, the latter owing to its supply from the medial anterior thoracic nerve (C. 8 and T. 1). The biceps and the brachio-radialis are paralysed and the brachialis (C. 5, 6, and 7) is greatly weakened. The elbow is generally extended owing to the action of the triceps (C. 7 and 8), which usually escapes. The supinators are all paralysed and the forearm is pronated by the pronator quadratus (C. 7, 8, and T. 1) alone, the pronator teres being supplied by C. 6. The radial extensors of the wrist being affected, the hand is deviated to the ulnar side, but all the other movements of the wrist and fingers are unchanged.

As the arm is fully pronated, the extensor digitorum communis and carpi ulnaris (C. 6, 7, and 8) may subsequently be able to produce a small degree of flexion at the elbow.

When the lesion is confined to the anterior ramus (primary division) of C. 5, no sensory changes can be discovered, as it is not responsible for the *exclusive* supply of any definite area of skin. If C. 6 also is involved, there is usually some loss of epicritic sensibility on the lateral aspects of the arm and forearm.

In the treatment of such conditions, the paralysed muscles must be relaxed or they will become overstretched by the unopposed action of the unparalysed antagonistic muscles.

Surgical approach to the plexus is described on p. 131.

Klumpke's Paralysis: Lower Arm Type.—This condition results from upward traction on the shoulder, *e.g.* when a man falling from a height seizes something to save himself, or in a breech presentation when the arms are carried up above the head. The lesion usually affects the first thoracic nerve, but it may involve the whole of the lower trunk (C. 8 and T. 1). The intrinsic muscles of the hand are paralysed and a characteristic claw-hand develops. (The fingers are hyper-extended at the metacarpo-phalangeal joints and flexed at the inter-phalangeal joints.) If the whole of the lower trunk is affected the flexors and extensors of the fingers are paralysed in addition (Sherren).

Diminution of sensibility occurs over the medial side of the arm, forearm, and hand, the area of protopathic loss being greater than the area of epicritic loss. When the first thoracic nerve is injured proximal to the point at which it sends off the white ramus communicans to the first thoracic ganglion of the sympathetic, the cilio-spinal reflex (p. 128) is abolished.

A Cervical Rib (p. 132) may produce a supra-clavicular lesion of the brachial plexus. In these cases the symptoms appear usually on the right side and indicate involvement of the lower trunk. No pupillary changes are present, as T. 1 is affected beyond the origin of its white ramus communicans. Neuralgic pain radiates down the ulnar side of the upper limb (Fig. 14), and there may be some epicritic loss in the same situation. Wasting and progressive paresis occur in the intrinsic muscles of the hand. Recent observations have shown that the same symptoms may be produced by the pressure of the first rib. This condition may result from a lowering of the point of the shoulder, following union of a fractured clavicle in poor alignment.

Injuries to the Cords of the Plexus.—The **Medial**

Cord may be torn or stretched in subcoracoid dislocation of the humerus or by the "heel in axilla" method of reduction. Sensory changes are found in the areas supplied by the ulnar, and the medial cutaneous nerves of the arm and forearm (Fig. 12). All the muscles supplied by the medial cord are paralysed, *i.e.* the intrinsic muscles of the hand, supplied by the ulnar and medial head of the median, and the flexor carpi ulnaris and the ulnar part of the flexor digitorum profundus, both supplied by the ulnar nerve.

The **Lateral Cord** may be injured in the same way. All the muscles supplied by the musculo-cutaneous nerve (biceps, coraco-brachialis, and brachialis, partly) and by the lateral head of the median (superficial and deep muscles of front of forearm) (p. 72) are paralysed. Partial epicritic insensibility exists in the areas supplied by the musculo-cutaneous and median nerves (Fig. 12).

Injury of the **Posterior Cord** produces all the signs of combined radial (musculo-spiral) and axillary (circumflex) paralyses.

Lesions of the Infra-clavicular Branches of the Plexus. Axillary (Circumflex) Nerve.—When this nerve is paralysed (p. 39) the deltoid atrophies and the bony landmarks become prominent—a condition which must be differentiated from wasting of the muscle following disease of the shoulder-joint. Lateral rotation is not greatly affected by the paralysis of the teres minor, but abduction can only be produced by the supra-spinatus. A marked loss of epicritic and protopathic sensibilities over the distal part of the deltoid always accompanies injury to the axillary (circumflex) nerve.

The Radial (Musculo-Spiral) Nerve may be pressed on in the axilla, *e.g.* "crutch" and "Saturday-night" paralysis. It is damaged in 8 per cent of fractures of the distal two-thirds of the shaft of the humerus, either at the time of the accident or in the subsequent formation of callus, and it has occasionally been injured in wiring ununited fractures of the humerus.

The *Dorsal Interosseous Nerve* is sometimes injured in fractures of the neck of the radius and in dislocations of that bone. It may be cut in operations which involve incisions into the supinator (s. brevis) (p. 65). The *Superficial Branch of the Radial Nerve* (*Radial Branch of Musculo-Spiral*) may be injured in wounds about the lateral and dorsal aspects of the wrist, but if no other nerves are involved, no sensory change is apparent (*vide infra*).

Injury to the Radial (Musculo-Spiral) nerve occurs most commonly in its distal third beyond the origin of its cutaneous branches and of the nerve-supply of the triceps and the anconæus. All the remaining muscles supplied directly by the radial (musculo-spiral) nerve and indirectly by its deep branch (posterior interosseous nerve) (p. 73) are paralysed, and the characteristic deformity of "Drop Wrist" develops. The patient is unable to extend his wrist or fingers, but, *if the first phalanges are supported when he attempts to do so, the lumbricals and interossei, which act in harmony with the extensor apparatus, will extend the fingers at the inter-phalangeal joints* (p. 84).

No sensory changes accompany injury to the radial (musculo-spiral) nerve in its distal third. Its superficial branch (radial nerve) is paralysed, but on account of the communications which it establishes with other nerves, no change of sensibility can be determined.

Note.—The dorsal branch of the lateral cutaneous (from the musculo-cutaneous nerve), the superficial (radial) branch of the radial (musculo-spiral) nerve, and the dorsal cutaneous nerve of the forearm (lower external cutaneous branch of the musculo-spiral) communicate with one another and overlap to such an extent that *no sensory symptoms are produced by section of any one of the nerves by itself*. If any two are injured there is some loss of epicritic and protopathic sensibility, extending from the bases of the lateral three digits to the dorsum of the wrist, but complete epicritic and protopathic loss in this area occurs only after division of all three (Sherren).

When the dorsal interosseous nerve is injured, the motor symptoms are the same as those described above, except that the brachio-radialis and extensor carpi radialis longus escape. As a result, the patient is able to extend the wrist, but the movement is weak.

The "Drop Wrist" of *lead poisoning* can be differentiated from both the above varieties, as the brachio-radialis is not affected while the extensor carpi radialis longus is paralysed.

Musculo-Cutaneous Nerve.—The main trunk of this nerve is rarely injured by itself, but the cutaneous portion or one of its branches may be cut in incisions and wounds of the forearm.

In injury of the main trunk, the biceps and the coraco-brachialis are paralysed and the brachialis is weakened (p. 41). Flexion of the forearm is still possible, and is performed by the brachialis and the superficial flexors of the forearm when the hand is supine, but, when the forearm is in the prone or mid-prone position, the brachio-radialis and the extensor carpi radialis longus assist in its production.

Epicritic and protopathic insensibility occurs over the radial half of the forearm. In front, the boundary line is very constant and runs from the line of the ring finger at the wrist to the tendon of the biceps. Dorsally the boundary line is not so definite and the insensitive area varies inversely with the size of the dorsal cutaneous nerve of the forearm (lower external cutaneous branch of the musculo-spiral nerve).

Section of the cutaneous portion of the musculo-cutaneous nerve produces the same sensory symptoms as those which result from injury of the main trunk. Section of its volar or of its dorsal branch produces no change in sensibility.

Medial Cutaneous Nerve of the Forearm (Internal Cutaneous Nerve).—When the main trunk of this nerve is cut, epicritic and protopathic sensibility are lost over the ulnar side of the forearm, but if one of the terminal branches is injured, epicritic sensibility alone is lost over the area involved.

Ulnar Nerve.—The ulnar nerve is liable to injury at the wrist, where it is exposed to cuts and stabs, and at the elbow, where it may be involved in fractures, dislocations, or operations on the joint.

1. *At the Wrist.*—The injury may occur either proximal or distal to the origin of the dorsal cutaneous branch, and, though the motor symptoms are exactly similar, the sensory changes are slightly different in the two cases.

All the intrinsic muscles of the hand, save those supplied by the median nerve (p. 86), are paralysed, and a characteristic deformity (partial *main en griffe*) is produced. In cases seen immediately after the accident, the injury to the nerve may be overlooked when no tendons are cut, as the patient appears, on superficial examination, to be able to perform most of the movements of the fingers. It is always essential in these cases to ask the patient to separate the fingers, and if he is unable to do so, paralysis of the dorsal interossei and of the abductor digiti quinti is at once discovered, and a more thorough examination should then be made. It should be observed that abduction of the fingers can be carried out by the extensor digitorum communis, but in this case *the movement is always accompanied by hyper-extension.*

In old-standing cases, the paralysed muscles atrophy and the fingers are extended at the metacarpo-phalangeal joints, as the balance between the flexors and extensors is lost, owing to paralysis of the interossei. In the little and ring fingers the balance is further upset by paralysis of the lumbrical muscles (p. 84), and as the action of these muscles on the dorsal extensor expansion (p. 92) is lost, hyper-extension at the metacarpo-phalangeal joints and flexion at the inter-phalangeal joints result, since the extensor communis digitorum is only capable of extending the fingers at the metacarpo-phalangeal joints.

When the ulnar nerve is cut *distal to the origin of its dorsal cutaneous branch*, epicritic sensibility is lost over the ulnar side of the palm, the palmar aspects of the little finger and ulnar side of the ring finger, and the dorsal aspects of the second and third phalanges of the same fingers. Protopathic loss varies, and deep sensibility is always present in these cases unless many tendons are cut. When the injury occurs *proximal to the origin of the dorsal cutaneous branch*, all the previous sensory symptoms are present, and, in addition, epicritic sensibility is lost over the ulnar side of the dorsum of the hand and over the dorsal aspects of the proximal phalanges of the little finger and ring fingers.

2. *At the Elbow.*—In injury of the ulnar nerve at this site, the additional muscular paralysis produces a slight change in the deformity of the hand. The portion of the flexor digitorum profundus destined for the ring and little fingers is paralysed, and therefore the terminal phalanges of these fingers are not flexed so acutely as in (1). Radial deviation of the hand occurs on flexion of the wrist owing to paralysis of the flexor carpi ulnaris.

The sensory changes are exactly similar to those which occur in section of the nerve at the wrist above the origin of the dorsal cutaneous branch. In addition, there is some loss of deep sensibility on the ulnar side of the palm.

Median Nerve.—The median nerve is most commonly injured as it lies between the tendons of the palmaris longus and the flexor carpi radialis at the proximal border of the transverse carpal ligament (p. 67). It is here cut by stab-wounds, the neighbouring tendons usually escaping injury.

Motor Symptoms.—The abductor and the flexor pollicis brevis, the opponens pollicis, and the first and second lumbricals are the only muscles affected. The thumb cannot be abducted (p. 84) completely, although the movement can be partially carried out by the abductor pollicis longus; on the other hand, the movement of opposition may be imitated by the flexor pollicis longus. When the patient is told to close the hand slowly, the index and middle fingers lag behind the other two, as the balance between the extensors and flexors is disturbed by the lumbrical paralysis (see Ulnar Nerve, p. 105). Hyper-extension of the index and middle fingers at the metacarpo-phalangeal joints is not always present, but adduction of the thumb is a characteristic feature when the hand is at rest.

Sensory Symptoms.—Epicritic sensibility is lost over the palm of the hand and over the area supplied by the digital branches. On the dorsal aspect, epicritic sensibility is lost over the second and third phalanges of the same fingers, but there is no sensory change on the dorsum of the thumb. The radial side of the thenar eminence is not affected. If many tendons are cut, as well as the nerve, deep sensibility is interfered with, and there is additional muscular paralysis.

When the median nerve is injured proximal to the bend of the elbow, the sensory symptoms are the same as those described above, but, in addition, deep sensibility is diminished over the palmar aspect of the hand and fingers. The amount of muscular paralysis is greatly increased, as the nerve is injured proximal to the origin of the branches supplying the muscles on the front of the forearm (p. 72). True pronation is lost, but the brachio-radialis carries the forearm from the supine into the mid-prone position, and then, if the arm is abducted, the weight of the hand can complete the action. Flexion of the wrist with ulnar deviation is performed by the flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus. The thumb is still adducted, but the terminal phalanx is kept extended owing to paralysis of the flexor pollicis longus. The index and middle fingers are practically useless, as no flexion is possible at the inter-phalangeal joints, and the interossei—which are the only flexor muscles unaffected—are but feeble flexors of the metacarpo-phalangeal joints when they have to initiate the movement. On the other hand, the ring and little fingers are weakened only by the loss of the flexor digitorum sublimis tendons.

It is in partial injuries of the median nerve that causalgia most commonly occurs in the upper limb. This is probably due to the fact that it carries most of the vaso-motor fibres to the vessels of the hand and forearm.

Segmental Innervation of the Muscles of the Superior Extremity.—The statements made in the foregoing pages regarding the segmental innervation of the individual muscles are substantially in agreement with the descriptions given in modern anatomical text-books, but they differ, in many instances, from the descriptions given by Kocher, whose views are based on clinical data. His conclusions are embodied in the following table :

Nerve.	**Muscles.**
C. V.	Rhomboids, supra- and infra-spinatus, deltoid, teres minor, coraco-brachialis, biceps, brachialis, brachioradialis, and supinator. (Abductors and lateral rotators of the shoulder ; flexors and supinators of forearm.)
C. VI.	Pectoralis major and minor, subscapularis, latissimus dorsi, teres major, serratus anterior, triceps, pronator teres, and pronator quadratus. (Adductors and medial rotators of shoulder ; extensors and pronators of forearm.)
C. VII.	Extensors and flexors of the wrist.
C. VIII.	Long flexors and extensors of the fingers.
T. I.	Small muscles of the hand.

THE HEAD AND NECK.

THE NECK.

Surface Landmarks.—The sterno-mastoid muscle, which is the most important landmark in the neck, forms an elevation, 1½ inches wide, between the anterior and posterior triangles. If its anterior border is traced upwards, the *mastoid process* can be felt lying under cover of the lobule of the ear, rather more than one inch above and behind the angle of the mandible. On deep pressure, midway between these two bony points, pain is elicited owing to the compression of the skin and parotid gland against the subjacent *transverse process of the atlas vertebra.*

In the anterior median line of the neck the *laryngeal prominence,* due to the forward projection of the thyreoid cartilage, forms a conspicuous landmark, which is more prominent in men than in women. The *greater cornu of the hyoid bone* is situated midway between the mastoid process and the laryngeal prominence, but, owing to its mobility, it cannot be made out unless the bone is steadied by placing a finger at the same level on the opposite side of the neck. When the greater cornu is traced forwards, the *body* of the hyoid bone can be examined. It lies about an inch above the laryngeal prominence and on a level with the lower part of the third cervical vertebra. The arch of the *cricoid cartilage*, which lies 1½ inches below the laryngeal prominence, is placed opposite the sixth cervical vertebra. If the finger is thrust backwards and laterally under cover of the anterior border of the sterno-mastoid at this level, the common carotid artery may be compressed against the anterior tubercle of the transverse process of the sixth cervical vertebra—the *carotid tubercle.*

The anterior border of the trapezius may be traced from its origin on the occipital bone downwards, round the side of the neck, to its insertion into the clavicle.

The *spine of the seventh cervical vertebra* can be identified as it lies at the lower end of the nuchal furrow ; the upper six cervical spines lie at the bottom of the nuchal furrow, and are obscured by the ligamentum nuchæ.

The Platysma.—This muscular sheet lies in the superficial fascia of the neck. Its anterior border runs obliquely upwards and medially. For a short distance below the chin it meets and decussates with the corresponding muscle of the opposite side, but the two muscles separate from one another below (Fig. 51). It is supplied on its deep surface by the cervical branch of the facial nerve. The platysma aids the facial muscles which drag downwards the lower lip and the angle of the mouth. Incisions which approach too near to the angle of the mandible (p. 138) may cut the nerve to the platysma (and depressor labii inf.) and cause paralysis of the movements indicated.

Superficial Nerves.—The skin of the front and side of the neck is supplied by branches from C. 2, C. 3, and C. 4. The nerves appear from under cover of the sterno-mastoid, near the middle of its posterior border, and radiate in various directions. Like the superficial veins, they lie deep to the platysma.

The descending, supra-clavicular, branches (C. 3 and C. 4) are described on p. 4.

The ascending branches are the *lesser occipital* (C. 2), which runs upwards along the posterior border of the sterno-mastoid to the scalp, and the *great auricular* (C. 2 and 3), which ascends across the muscle superficially, and supplies the skin over the angle of the jaw and the postero-inferior part of the auricle. The great auricular nerve usually accompanies the upper half of the external jugular vein (Fig. 35).

These nerves are commonly divided in operations for the removal of tuberculous lymph glands, and occasionally their cut ends become adherent to the scar. Neuralgia, arising from this cause, radiates over the area supplied by the other nerves which arise from the same segment of the spinal medulla as the nerve involved. The surgeon may resect the superficial nerves of the neck as soon as they are exposed as a prophylactic measure, and, although some loss of sensation may result, the condition gradually improves.

Posteriorly, the skin is supplied by the posterior rami (primary divisions) of the second to the sixth cervical nerves.

The line of anæsthesia in fracture dislocations below the fourth cervical vertebra is described on p. 537.

The **External Jugular Vein** is formed at the lower border of the parotid gland by the union of the posterior auricular and a branch (the posterior division of the temporo-maxillary) from the posterior facial vein (Fig. 35). It is visible as it descends vertically across the sterno-mastoid to the angle between its posterior border and the clavicle, where it enters the subclavian vein after piercing the deep fascia. About its mid-point the external jugular vein receives a tributary, which drains the superficial tissues of the posterior aspects of the scalp and the neck. After piercing the deep fascia, it is joined on its lateral side by the transverse cervical and transverse scapular (suprascapular) veins, and on its medial side by the anterior jugular.

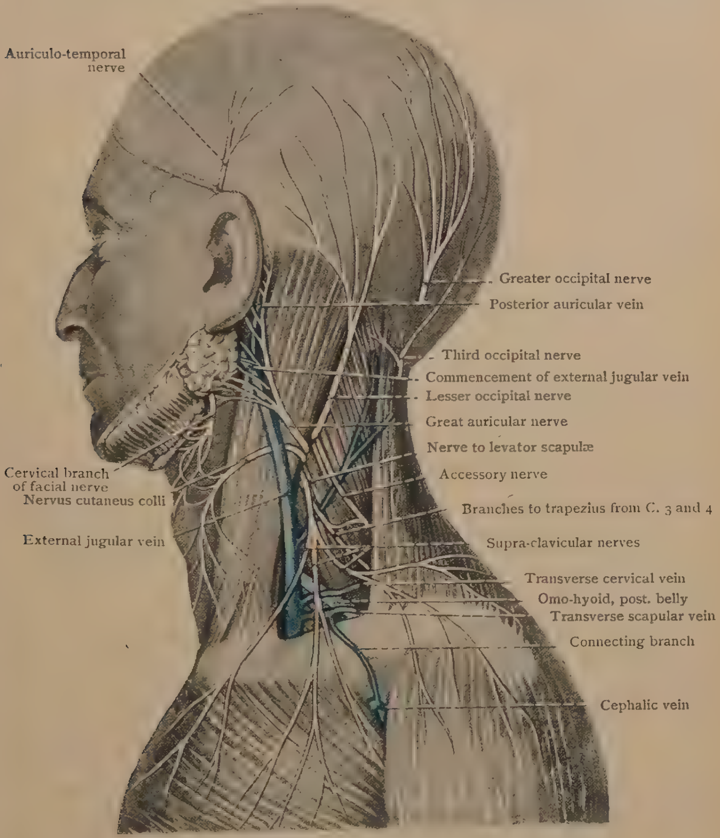

Auriculo-temporal nerve
Greater occipital nerve
Posterior auricular vein
Third occipital nerve
Commencement of external jugular vein
Lesser occipital nerve
Great auricular nerve
Nerve to levator scapulæ
Accessory nerve
Cervical branch of facial nerve
Nervus cutaneus colli
Branches to trapezius from C. 3 and 4
External jugular vein
Supra-clavicular nerves
Transverse cervical vein
Omo-hyoid, post. belly
Transverse scapular vein
Connecting branch
Cephalic vein

FIG. 35.—Superficial Nerves and Veins of the Neck.

The vein wall is very adherent to the margins of the opening in the deep fascia through which it passes, and at this point, therefore, the vein cannot collapse. If the vessel is cut in this region there is danger lest air be drawn in by the suction of the chest in inspiration, and on this account the finger should immediately be applied over such a wound. In its upper half the external jugular vein is commonly accompanied by the great auricular nerve, and throughout its whole course it is closely related to the superficial cervical lymph glands.

Owing to its superficial position, the external jugular vein may be opened to relieve the venous congestion which sometimes occurs during the administration of an anæsthetic from distention of the right side of the heart.

The **Anterior Jugular Vein** arises just below the chin and runs downwards near the anterior median line of the neck (p. 166). It turns laterally deep to the sterno-mastoid, just above the clavicle, and joins the external jugular vein close to its termination. Occasionally the anterior jugular is joined by the common facial vein. The two anterior jugular veins are connected by a transverse branch (Fig. 51) which lies in the suprasternal space (of Burns) (p. 113).

The superficial veins of the neck vary considerably in size, and the increase of one is balanced by the decrease of another.

The **Superficial Cervical Lymph Glands** lie in the superficial fascia of the neck. They consist of three groups, (A) Occipital, (B) Mastoid, and (C) a chain of glands accompanying the external jugular vein.

A. The Occipital lymph glands lie at the apex of the posterior triangle. They receive afferents from the posterior part of the scalp, and are commonly enlarged in pediculosis or impetigo of the area which they drain. Their efferents pass partly to group (C), and partly to the upper posterior group of the deep cervical lymph glands (p. 136).

B. The Mastoid lymph glands lie on the upper part of the sterno-mastoid. They drain the adjoining area of the scalp and the deep surface of the pinna, and their efferents take the same course as the efferents of the occipital glands.

C. This group receives afferents from the Occipital and Mastoid lymph glands, which are the usual sources of infection. They are not liable to tuberculous disease, and therefore, when they become enlarged, there is very little periadenitis, so that they can easily be felt to slip about beneath the platysma.

Deep Cervical Fascia.—The deep fascia of the neck consists of an investing layer and of several subsidiary processes.

(*a*) The **Investing Layer** forms the roof of the anterior triangle, and is firmly bound down to the hyoid bone. Traced laterally, it encloses the sterno-mastoid, forms the roof of the posterior triangle, and then invests the trapezius (Fig. 36). It is attached above to the lower border of the mandible, but, in the neighbourhood of the angle, it is carried upwards, enclosing the parotid gland, to the zygomatic arch and the antero-inferior border of the external acoustic (auditory) meatus. It is attached to the mastoid process, the superior nuchal line of the occipital bone, and the external occipital protuberance, *i.e.* it corresponds to the attachments of the sterno-mastoid and the trapezius.

Between the angle of the mandible and the greater cornu of the hyoid bone, the investing layer blends with the fascial sheath of the posterior belly of the digastric; between the chin and the greater cornu a similar connection is formed with the fascial sheath of the anterior belly of the digastric. In this way the submaxillary and submental regions are shut off from one another and from the rest of the neck (p. 149).

Just above the jugular (suprasternal) notch the investing layer splits into two lamellæ, which are attached to the front and back of the manubrium sterni. The space between them—*the suprasternal space (of Burns)*—contains one or two lymph glands and a communication between the two anterior jugular veins (Fig. 51). Traced laterally, these two layers enclose the sterno-mastoid, and pass down to the clavicle. In the lower part of the posterior triangle the same two layers can again be recognised, and, for about an inch above the clavicle, they are separated by some loose fat. The deeper layer encloses the posterior belly of the omo-hyoid, and holds it down in place; the superficial layer, which is very thin and ill-defined, is continuous with the fascia covering the trapezius.

The investing layer is much stronger over the triangles than it is over the trapezius and the sterno-mastoid. So firmly does it bind the structures together that, in operations on the neck, good exposure can be obtained only after it has been divided freely. In flap operations the flap should consist of all the tissues down to and including the deep cervical fascia.

(*b*) The **Prevertebral Fascia** covers the muscles which are closely applied to the anterior aspects of the cervical vertebræ. It is attached above to the basi-occiput, and it passes down as a thick sheet into the thorax, where it blends with the anterior longitudinal (common) ligament. Traced laterally, the prevertebral fascia gradually becomes thinner. It passes behind the great vessels of the neck and covers the muscles on which they lie, viz. the longus colli, the longus capitis (rectus capitis anticus major), and the scalenus anterior. It is then continued on to the surfaces of the adjacent muscles, viz. the splenius capitis, the levator scapulæ, the scalenus medius and posterior, *i.e. it forms the fascial floor of the posterior triangle.* As the anterior rami (primary divisions) of the cervical nerves lie on the upper surfaces of the transverse processes of the vertebræ, they are situated behind the prevertebral fascia. The superficial branches of the cervical plexus soon pierce it, but the phrenic nerve lies deep to the fascia as it runs down in front of the scalenus anterior. When the roots of the brachial plexus and the subclavian artery emerge from under cover of the scalenus anterior, they carry the prevertebral fascia with them downwards and laterally towards the apex of the axilla, and so form the axillary

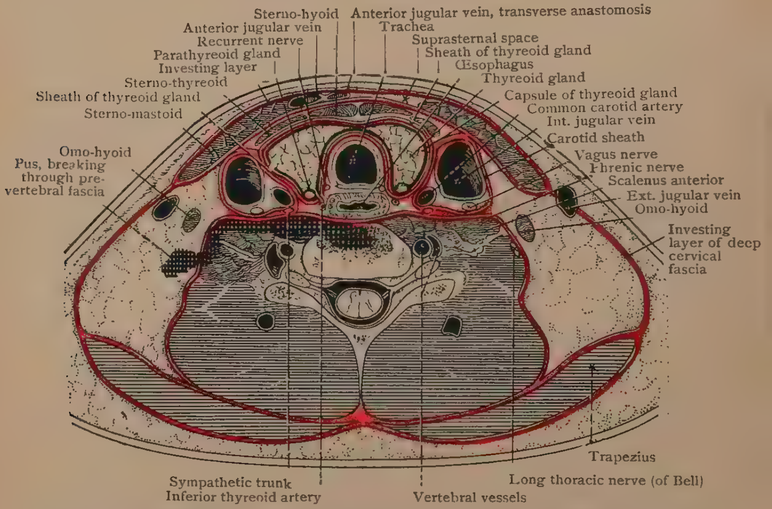

Sterno-hyoid
Anterior jugular vein, transverse anastomosis
Anterior jugular vein
Trachea
Recurrent nerve
Suprasternal space
Parathyreoid gland
Sheath of thyreoid gland
Investing layer
Œsophagus
Sterno-thyreoid
Thyreoid gland
Sheath of thyreoid gland
Capsule of thyreoid gland
Sterno-mastoid
Common carotid artery
Int. jugular vein
Carotid sheath
Omo-hyoid
Pus, breaking through prevertebral fascia
Vagus nerve
Phrenic nerve
Scalenus anterior
Ext. jugular vein
Omo-hyoid
Investing layer of deep cervical fascia
Trapezius
Sympathetic trunk
Long thoracic nerve (of Bell)
Inferior thyreoid artery
Vertebral vessels

FIG. 36.—Transverse Section through Neck, at level of Seventh Cervical Vertebra, showing the arrangement of the Deep Cervical Fascia. On the left side, a tuberculous abscess is shown, originating in the body of a vertebra and spreading laterally behind the prevertebral fascia. After eroding the muscles, it has penetrated the prevertebral fascia and made its way into the posterior triangle of the neck.

sheath. It will be seen from Fig. 36 that the prevertebral fascia, after covering the floor of the posterior triangle, blends with the fascia on the deep surface of the trapezius and reaches the ligamentum nuchæ. In this way it forms a complete layer around the neck, but it lies on a deeper plane than the investing layer.

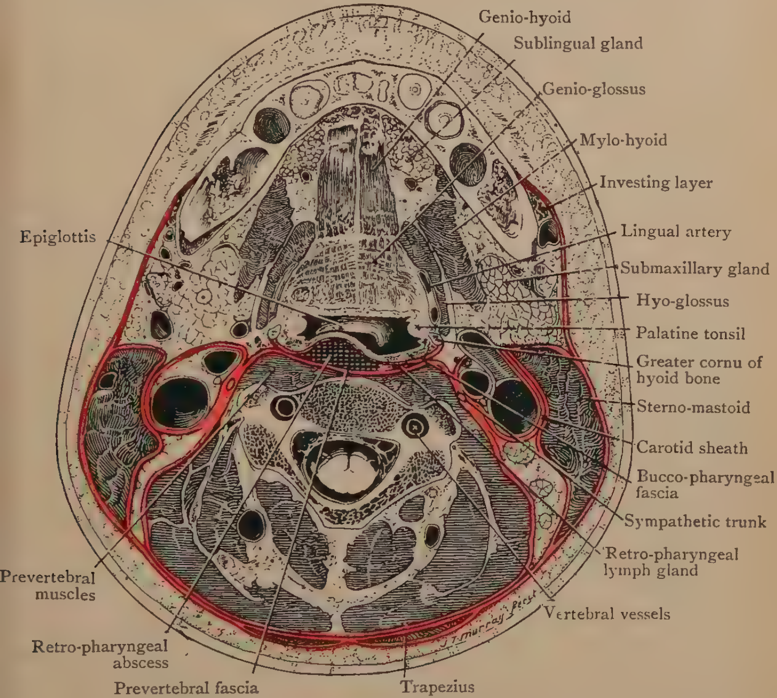

Genio-hyoid
Sublingual gland
Genio-glossus
Mylo-hyoid
Investing layer
Lingual artery
Submaxillary gland
Hyo-glossus
Palatine tonsil
Greater cornu of hyoid bone
Sterno-mastoid
Carotid sheath
Bucco-pharyngeal fascia
Sympathetic trunk
Retro-pharyngeal lymph gland
Vertebral vessels
Trapezius
Prevertebral fascia
Retro-pharyngeal abscess
Prevertebral muscles
Epiglottis
J. T. Murray fecit

FIG. 37.—Transverse Section through the Neck of a Child, at the level of the Third Cervical Vertebra, showing the arrangement of the Deep Cervical and Bucco-pharyngeal fasciæ. An abscess is shown in the retro-pharyngeal space, originating in one of the lymph glands in that situation. Its relation to the prevertebral fascia should be carefully noted. Cf. Fig. 50.

Pus arising from tuberculous disease of the upper cervical vertebræ lies behind the prevertebral fascia (Fig. 36). It forms a swelling on the posterior wall of the pharynx which causes difficulty in swallowing and respiration. Owing to the strength of the fascia in the median plane, the pus travels downwards and laterally behind the carotid sheath and reaches the posterior triangle. In this situation the fascia is much weaker, and the abscess points behind the sterno-mastoid. It is best approached by an incision along the posterior border of the muscle (Chiene), which is then retracted forwards together with the carotid sheath. A search is made for the transverse processes of the cervical vertebræ, which provide the deep landmarks to the site of the abscess (p. 527). Rarely, the pus travels downwards behind the prevertebral fascia and enters the mediastinal space. This variety of abscess must be distinguished from an abscess originating in the lymph glands which occupy the interval between the prevertebral fascia and the bucco-pharyngeal fascia on the outer surface of the constrictor muscles (Fig. 37). They drain the naso-pharynx, and their efferents pass laterally to open into the upper group of the deep cervical lymph glands. An abscess arising in connection with the retro-pharyngeal lymph glands causes a swelling on the posterior wall of the pharynx, usually to one or other side of the median plane. Should it rupture into the pharynx during sleep, it may lead to suffocation. Abscesses in front of the prevertebral fascia should be opened from the mouth with the patient's head inverted (Rose's position), but this route is avoided in dealing with pus behind the prevertebral fascia—which is tuberculous in origin—on account of the danger of mixed infection.

(*c*) The **Pretracheal Fascia** is a much thinner sheet than the prevertebral and lies in front of the trachea and the lower part of the larynx, forming a fascial sheath for the thyreoid gland (p. 171) under cover of the depressor muscles of the hyoid bone (Fig. 36). The pretracheal fascia covers the crico-thyreoid muscle and is firmly adherent to the cricoid and thyreoid cartilages. It does not extend upwards beyond the thyreoid cartilage but, inferiorly, it descends into the superior mediastinum and blends with the outer coat of the arch of the aorta. Laterally the pretracheal fascia blends with the anterior wall of the carotid sheath.

(*d*) **The Carotid Sheath.**—The common and internal carotid arteries, the internal jugular vein, and the vagus nerve are surrounded by, and embedded in, a tubular investment of the deep cervical fascia. The sheath is best seen in relationship to the upper half of the common carotid artery: above and below that area it gradually becomes indefinite. The posterior wall of the sheath is connected to the prevertebral fascia by some loose connective tissue, which, however, does not prevent pus from spreading laterally between them; its anterior wall fuses with the pretracheal fascia. The sheath is very thin where it is in contact with the internal jugular vein, but forms a dense covering for the common carotid artery.

Relations of the Carotid Sheath.—The carotid sheath is so frequently exposed in operations on the neck that its relations require careful consideration. At its lower end it is covered by the sterno-hyoid and the sterno-thyreoid muscles and, more superficially, by the sternal head of the sterno-mastoid. Between these two muscular layers the anterior jugular vein runs laterally, just above the clavicle, and hence it runs the risk of injury when these muscles are separated. Opposite the cricoid cartilage, the sheath is crossed obliquely by the anterior belly of the omo-hyoid (Fig. 38). (The intermediate tendon of the muscle exactly overlies the internal jugular vein.) Above that level, the carotid sheath is overlapped by the anterior border of the sterno-mastoid, but, just below the mandible, it appears partially from under cover of the muscle. Above the level of the hyoid bone the great vessels pass deep to the posterior belly of the digastric and the stylo-hyoid. Numerous tributaries of the internal jugular vein (p. 119) cross the medial part of the sheath to reach their destination. Opposite the hyoid bone the sheath is crossed transversely by the hypoglossal nerve (p. 127) and, at the upper border of the omo-hyoid, by the branch from the superior thyreoid artery to the sterno-mastoid.

Posteriorly, the sheath rests on the longus colli in its lower part, and it forms the roof of the deep triangle of the neck (p. 142). Superiorly, it lies on the transverse processes of the cervical vertebræ and on the muscles which arise from them, viz. the scalenus anterior and the longus capitis (rectus cap. antic. major). The sheath extends laterally so as to overlap the phrenic nerve as it lies on the scalenus anterior.

On its *medial side* the carotid sheath is closely applied to the trachea, the œsophagus, and the recurrent (laryngeal) nerve; the posterior border of the lateral lobe of the thyreoid gland is an intimate relation and may overlap the sheath, while, at a higher level, the inferior and middle constrictors of the pharynx and the thyreo-hyoid membrane lie to its medial side.

Laterally, the sheath is related to the deep surface of the sterno-mastoid, save where the depressors of the hyoid bone intervene.

Within the carotid sheath lie the common carotid and the commencement of the internal carotid artery, the internal jugular vein, the vagus nerve, and some lymph glands. The artery is situated medially and on a plane somewhat anterior to the internal jugular vein, but it is overlapped by the vein, which is considerably the larger of the two vessels. The vagus nerve lies between and behind the artery and the vein. The ramus descendens hypoglossi (p. 158) is embedded in the anterior aspect of the sheath.

(*e*) The **Stylo-mandibular Ligament** connects the styloid process to the deep surface of the angle of the mandible. It forms a part of the sheath of the parotid gland, and it separates the parotid from the submaxillary region.

The **Sterno-mastoid Muscle** arises by a sternal and a clavicular head, separated from one another by a triangular interval, in the floor of which lies the lower end of the carotid sheath. The fibres of the muscle pass upwards and backwards to the mastoid process and the superior nuchal line of the occipital bone. The muscle is firmly held in place by the deep fascia, and its anterior border shows a forward convexity which disappears when the fascia is incised along it, permitting the carotid sheath to come into view. The *nerve-supply* of the sterno-mastoid is derived from the accessory (spinal accessory) nerve and the anterior ramus (primary division) of C. 2. When the accessory nerve is cut, the muscle of the opposite side, being unopposed, draws the head down to its own side, and at the same time rotates and tilts the head so that the chin is directed upwards and towards the affected side. In these cases, therefore, the torti-collis is found on the other side of the neck from the causative lesion. *Congenital torti-collis* is due to shortening of the muscle of the same side, either from mal-development or from cicatricial fibrosis following rupture during parturition.

Acquired torti-collis may be due to astigmatism, or to the irritation of the second cervical nerve by Potts' disease, or it may be caused by the pressure of inflamed lymph glands on the accessory nerve. This variety can always be distinguished from the true form by the absence of facial asymmetry.

In the treatment of congenital torti-collis, subcutaneous tenotomy of the sterno-mastoid near its origin has fallen into disuse on account of the danger of wounding the anterior or the external jugular vein (p. 110). In addition, the deep cervical fascia, which is also contracted, must be divided in order to ensure a successful result, and this proceeding cannot be carried out by the subcutaneous method. At the present time an open operation is performed through an oblique incision across the lower part of the muscle. The deep fascia is freely incised, and the muscle is divided along with the fascia on its deep surface. It may even be necessary to open the carotid sheath to obtain sufficient relaxation.

The **Internal Jugular Vein** is a direct downward continuation of the transverse (lateral) sinus, and it emerges from the skull at the posterior part of the jugular foramen. In its uppermost part it is rarely seen by the surgeon, since it lies deeply, under cover of the styloid process and the parotid gland. It descends in the carotid sheath, the relations of which are described on p. 117, and it is covered by the sterno-mastoid muscle. In the sheath the vein lies on the lateral side of the common carotid artery and its terminal branches, but it overlaps them anteriorly. When an opening is made in the carotid sheath, the vein bulges through and it is easily recognised by its blue-grey colour. If the venous return to the heart is obstructed in any way, the internal jugular vein shares in the general engorgement and becomes greatly distended. In the lower part of the neck the vein crosses in front of the first part of the subclavian artery, and it terminates behind the sternal end of the clavicle by uniting with the subclavian to form the innominate vein.

Malignant and tuberculous lymph glands frequently become adherent to the internal jugular vein, and it is not uncommon for the surgeon to *resect a portion of the vessel* in order to facilitate their removal. The vein is first isolated inferiorly, and it is then divided between ligatures as low down as necessary. The vein is then dissected upwards—a procedure which is easier than the reverse method, because numerous tributaries join the vein in its upper part and render its isolation extremely difficult. The portion most commonly resected receives the common facial vein, which must also be ligatured and divided. The rise in pressure in the internal jugular vein during vomiting is so great that lateral ligatures may be forced off. Consequently, if the vein is wounded during an operation, it is much safer to divide it completely and ligature both the cut ends.

The **Common Facial Vein** is the most important tributary of the internal jugular, and it serves as a useful landmark in removal of the tonsillar and the upper anterior group of the deep cervical lymph glands (p. 136). It is formed at the lower border of the submaxillary gland by the union of the anterior and posterior facial veins (facial and anterior division of temporo-maxillary vein); the former drains the muscles and tissues of

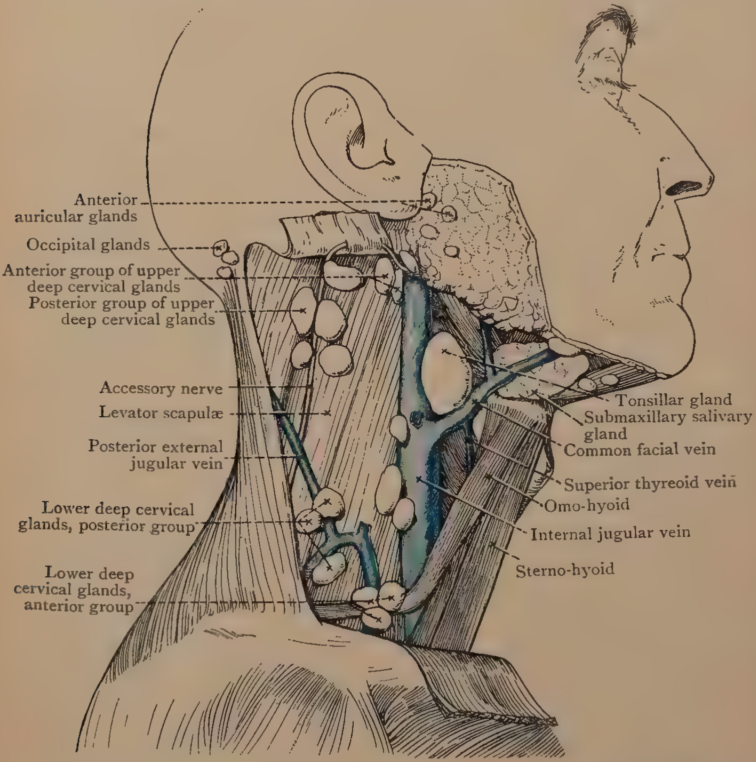

Anterior auricular glands
Occipital glands
Anterior group of upper deep cervical glands
Posterior group of upper deep cervical glands
Accessory nerve
Levator scapulæ
Posterior external jugular vein
Lower deep cervical glands, posterior group
Lower deep cervical glands, anterior group
Tonsillar gland
Submaxillary salivary gland
Common facial vein
Superior thyreoid vein
Omo-hyoid
Internal jugular vein
Sterno-hyoid

FIG. 38.—The Veins and Lymph Glands of the Neck. The upper part of the external jugular vein has been resected. The sterno-mastoid has been cut across below the point at which it is pierced by the accessory nerve, and the two cut ends have been turned upwards and downwards respectively.

the face, while the latter emerges from the substance of the parotid gland. The common facial vein passes backwards and downwards, superficial to the carotid sheath, which it pierces opposite the greater cornu of the hyoid bone. Its direction is often altered by enlarged lymph glands. Sometimes it runs horizontally backwards, and sometimes almost vertically downwards; in the latter case it may be mistaken for the internal jugular vein. It usually receives the superior thyreoid, lingual, and tonsillitic veins. The last two are found under cover of the posterior belly of the digastric, and often open directly into the internal jugular vein. Not infrequently the common facial ends by joining the anterior jugular vein, which is considerably increased in size in these cases.

The **Superior Thyreoid Vein** generally ascends to enter the common facial, but it may join the internal jugular directly by crossing the common carotid artery.

The **Middle Thyreoid Vein**, which appears from under cover of the anterior belly of the omo-hyoid, enters the internal jugular vein after piercing the anterior aspect of the carotid sheath (p. 122).

The Common Carotid Artery.—On the right side, the common carotid artery arises from the innominate artery behind the sterno-clavicular joint; on the left side, it arises from the arch of the aorta and lies in the superior mediastinum for 1¼ inches. The course of the artery in the neck can be mapped out by a line drawn from the sterno-clavicular joint to a point midway between the angle of the mandible and the mastoid process. Opposite the upper border of the thyreoid cartilage, which lies at the level of the fourth cervical vertebra, the common carotid ends by dividing into the internal and external carotid arteries. As it lies in front of the carotid tubercle (p. 109), the artery is crossed by the anterior belly of the omo-hyoid, which is running upwards, forwards, and medially.

Ligature of the common carotid artery above the omo-hyoid is performed for congenital hydrocephalus (Stiles), or for aneurism of the innominate artery. Temporary occlusion of the vessel by Crile's method may be carried out in this part of its course as a preliminary step to extensive operations on the mouth or throat. This proceeding is dangerous in elderly people, since it may induce cerebral softening (p. 122), and in these patients the external carotid should be selected. The *incision* may be made along or obliquely across the anterior border of the sterno-mastoid. The skin, superficial fascia, and the platysma are divided, and the investing layer of the deep cervical fascia is cut through at the anterior border of the sterno-mastoid, thus allowing the muscle to be retracted to the lateral side. The omo-hyoid, which is now exposed, is an important landmark, as it indicates the proximity of the vessel. It is drawn downwards and medially, bringing the middle thyreoid veins into view, and the carotid sheath is opened on its medial side to avoid injuring the internal jugular vein.

Ligature below the omo-hyoid is performed for aneurism of the distal part of the artery. This operation is more difficult than the preceding one, because the vessel lies more deeply and is placed under cover of the sterno-hyoid and sterno-thyreoid muscles. The incision extends somewhat lower, and after retracting the sterno-mastoid laterally, the surgeon draws the omo-hyoid upwards and laterally, and the sterno-hyoid and sterno-thyreoid downwards and medially.

In both these operations care must be taken not to include the vagus or the sympathetic trunk in the ligature. If the sympathetic is injured, unilateral sweating of the head and neck, contraction of the pupil, and retrogression of the eyeball will occur on the affected side.

After ligature of the common carotid the *collateral circulation* is carried out by (1) the occipital anastomosis ; (2) the thyreoid anastomosis ; (3) the anastomosis which is established by the branches of the external carotid arteries, lingual, external maxillary (facial), etc. across the median plane.

1. In the occipital anastomosis, the ascending branch of the transverse cervical (p. 130), the profunda cervicis (p. 141), and the ascending cervical (p. 147), which are all derived from the *subclavian artery*, anastomose with the descending and muscular branches of the occipital artery. This anastomosis takes place on the superficial and deep surfaces of the semispinalis capitis (complexus).

2. The thyreoid anastomosis occurs between the superior and inferior thyreoid arteries in and around the thyreoid gland. This anastomosis also establishes a connection between the external carotid and the subclavian arteries.

When the common carotid artery is ligatured, the brain receives a sufficient, though diminished, blood-supply, owing to the free anastomosis established by the arterial circle (of Willis). In infants suffering from hydrocephalus, one common carotid having been ligatured, the other may be tied after a short interval without any deleterious effects on the nutrition of the brain (Stiles), but in adults the ligature of one common carotid alone may produce cerebral softening.

The **External Carotid Artery** begins opposite the upper border of the thyreoid cartilage and ends in the parotid gland, behind the neck of the mandible, by dividing into the internal maxillary and superficial temporal arteries. The course of the artery corresponds to a line drawn from a little below the tip of the greater cornu of the hyoid bone to the lobule of the auricle.

In *ligature* of this part of the vessel the incision may be made in the natural folds of the neck, either along the anterior border of the sterno-mastoid or crossing the muscle obliquely. The superficial coverings are divided, and, in the oblique incision, the external jugular vein and the great auricular nerve (p. 110) will be exposed in the upper part of the wound. The deep fascia is cut along the anterior border of the sterno-mastoid, and the muscle, which overlaps the artery, is retracted to the lateral side. Numerous veins (pharyngeal, lingual, and common facial) cross the external carotid artery to reach the internal jugular vein. They must be secured before the upward continuation of the carotid sheath is opened. Care must be taken not to open the sheath too much to the medial side lest the superior thyreoid artery be injured as it descends medial to the sheath. The vessel is ligated between the superior thyreoid and lingual branches, *i.e.* a short distance below the greater cornu of the hyoid bone. In this operation there is little danger of including the vagus nerve in the ligature, since it is a more intimate relation of the internal carotid artery, which lies on a deeper plane.

The upper part of the external carotid artery disappears by passing under cover of the stylo-hyoid and the posterior belly of the digastric, but before it does so it is crossed from behind forwards by the hypoglossal nerve (Fig. 39). Throughout the rest of its course the artery lies deeply, under cover of the parotid gland, and is rarely exposed by the surgeon.

The **Superior Thyreoid Artery** arises from the external carotid just above the upper border of the thyreoid cartilage, and runs downwards and forwards, disappearing under cover of the omo-hyoid and the sterno-thyreoid to supply the thyreoid gland (p. 171). It may be ligated near its origin by an incision similar to that employed for ligature of the external carotid. The superior cornu of the thyreoid cartilage is the deep surgical guide to the vessel. The branches are (1) the *Superior Laryngeal Artery*, which pierces the thyreo-hyoid membrane at the posterior border of the thyreo-hyoid muscle, in company with the internal laryngeal nerve (p. 163); (2) the *Crico-thyreoid Artery* (p. 166); and (3) a branch of supply to the sterno-mastoid (p. 117).

The **Lingual Artery** (p. 149) arises from the external carotid opposite the greater cornu of the hyoid bone. It makes an upward loop, and then passes deep to the posterior border of the hyo-glossus muscle, and gains the submaxillary region. This loop permits the hyoid bone to be elevated without putting an undue strain on the vessel. In *ligature* of the lingual artery, preparatory to removal of the tongue, the first part of the vessel is usually selected, as it is then secured before its important branches to the tongue and the palatine tonsil are given off. The *incision* is practically the same as for ligature of the external carotid (p. 123). The greater cornu of the hyoid bone is the superficial guide to the vessel, and the posterior belly of the digastric is a convenient guide to the depth which has been reached. Immediately below the muscle the hypoglossal nerve (p. 127) crosses the arterial loop, and tributaries of the internal jugular vein often obscure both the nerve and the artery.

The **External Maxillary (Facial) Artery** arises from the external carotid immediately above the lingual or occasionally by a common trunk with it. Immediately after its origin it passes upwards under cover of the stylo-hyoid and the posterior belly of the digastric and enters the submaxillary region (p. 151). The procedure already described for ligature of the lingual artery may be followed in ligating this vessel.

The **Occipital Artery** arises from the posterior aspect of the external carotid artery at the same level as the external maxillary (facial). It runs upwards and backwards along, or deep to, the lower border of the posterior belly of the digastric, and disappears under cover of the mastoid process and the muscles attached to it. In the first part of its course it crosses superficial to the internal jugular vein and the accessory nerve. As it crosses the latter it gives off a branch to the sterno-mastoid, and this, when cut, may serve to indicate the proximity of the nerve. Close to its origin the occipital artery is crossed by the hypoglossal nerve, which descends along the lateral side of the internal carotid and bends sharply forwards at this point (Fig. 39).

The **Accessory (Spinal Accessory) Nerve** leaves the skull through the middle compartment of the jugular foramen. At first it lies between the internal carotid and the internal jugular vein. Opposite the transverse process of the atlas the nerve crosses the vein and runs downwards and laterally. It is crossed by the occipital artery, and 1½ inches below the tip of the mastoid process it pierces the sheath of the sterno-mastoid. Accompanied by a branch from the occipital artery, it enters the muscle, which it supplies. Its subsequent course is described on p. 129.

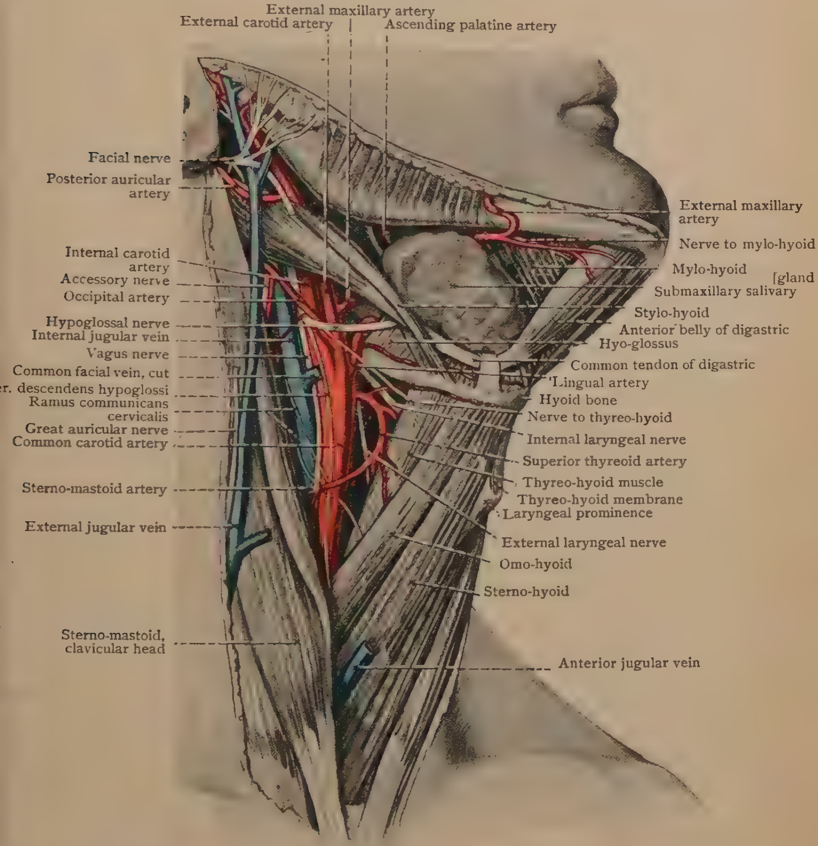

External maxillary artery
External carotid artery
Ascending palatine artery
Facial nerve
Posterior auricular artery
Internal carotid artery
Accessory nerve
Occipital artery
Hypoglossal nerve
Internal jugular vein
Vagus nerve
Common facial vein, cut
r. descendens hypoglossi
Ramus communicans cervicalis
Great auricular nerve
Common carotid artery
Sterno-mastoid artery
External jugular vein
Sterno-mastoid, clavicular head
External maxillary artery
Nerve to mylo-hyoid
Mylo-hyoid
Submaxillary salivary [gland
Stylo-hyoid
Anterior belly of digastric
Hyo-glossus
Common tendon of digastric
Lingual artery
Hyoid bone
Nerve to thyreo-hyoid
Internal laryngeal nerve
Superior thyreoid artery
Thyreo-hyoid muscle
Thyreo-hyoid membrane
Laryngeal prominence
External laryngeal nerve
Omo-hyoid
Sterno-hyoid
Anterior jugular vein

FIG. 39.—The Side of the Neck. The anterior border of the sterno-mastoid has been retracted in order to expose the underlying vessels and nerves.

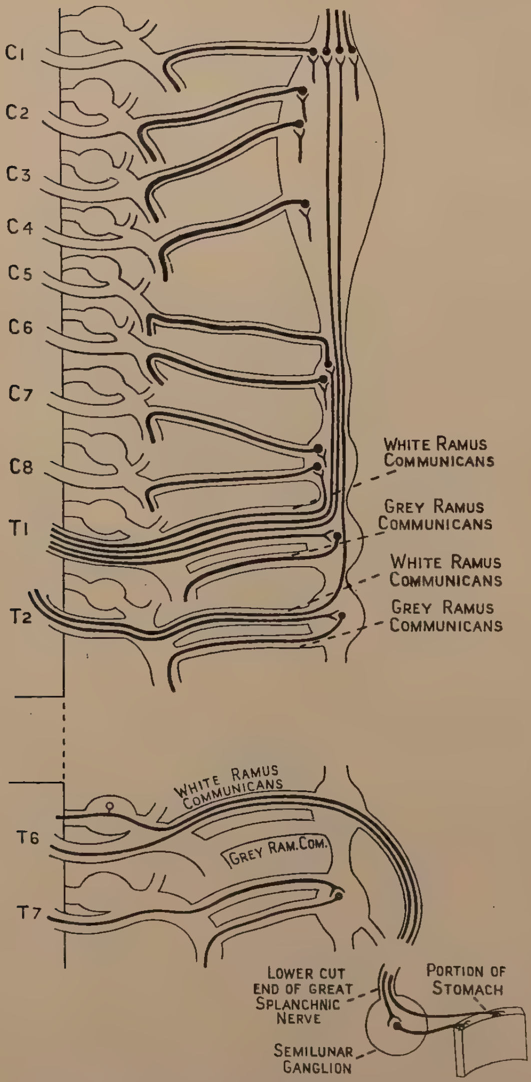

C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
White Ramus Communicans
Grey Ramus Communicans
White Ramus Communicans
Grey Ramus Communicans
White Ramus Communicans
Grey Ram. Com.
T6
T7
Lower cut end of great Splanchnic Nerve
Portion of Stomach
Semilunar Ganglion

Fig. 40.—Diagram to illustrate the arrangement and mode of behaviour of some of the fibres of the Sympathetic System in the cervical and thoracic regions.

The **Hypoglossal Nerve** lies deeply, under cover of the parotid gland, in the upper part of its course, and it descends between the internal jugular vein and the internal carotid artery. It appears at the lower border of the posterior belly of the digastric, and bends forwards almost at right angles, hooking round the occipital artery. It crosses superficial to the internal and external carotid arteries and to the loop formed by the lingual, and it is itself crossed by the lingual veins. It runs forwards, a little above the level of the hyoid bone, and disappears under cover of the posterior belly of the digastric (Fig. 39). It reappears above the common tendon of the digastric, lying on the hyo-glossus. On reaching the posterior border of the mylo-hyoid, the nerve enters the intermuscular space between this muscle and the hyoglossus (p. 158), and so reaches the muscles of the tongue, which it supplies. In the superficial part of its course it gives off a descending branch (p. 158) and the nerve of supply to the thyreo-hyoid.

The **Sympathetic Trunk** in the neck is embedded in the posterior wall of the carotid sheath, and lies posterior to the common and internal carotid arteries and medial to the vagus nerve. It possesses three ganglia, and these send afferent fibres to the spinal medulla and efferent fibres to the blood-vessels, sweat-glands, etc., of the head, neck, and upper limb.

The AUTONOMIC SYSTEM comprises all parts of the nervous system which are concerned with (1) the excitation or inhibition of plain muscle, whether in the walls of viscera or blood-vessels; (2) the activities of glands. It may be subdivided into two parts (*a*) the *Sympathetic* and (*b*) the *Parasympathetic* system, which are commonly distributed to the same viscera and then have opposite effects.

The *Sympathetic System* includes the two gangliated trunks, their branches and collateral ganglia. Typically, the trunk has a ganglion corresponding to each spinal nerve, but in certain situations two or more adjoining ganglia have become fused. In the cervical region the upper four ganglia fuse to form the superior, the fifth and sixth fuse to form the middle, and the seventh and eighth fuse to form the inferior cervical ganglion. In the thoracic region there are usually eleven, in the lumbar four, and in the sacral four, fusion of adjoining ganglia having occurred in each of these regions. The two ends unite in the median ganglion impar in front of the coccyx.

Each ganglion communicates with the spinal nerve or nerves to which it corresponds by one or more *grey rami communicantes*. In addition, the thoracic and upper lumbar (T. 1 or 2—L. 2 or 3) ganglia are connected to the corresponding spinal nerves by *white rami communicantes.*

The ultimate origin of the efferent fibres which are distributed, after being relayed in a ganglion, by the sympathetic is unknown. It is clear that the fibres descend through the cervical part of the spinal medulla and pass out along those anterior nerve roots which communicate with the sympathetic by means of white rami communicantes. These outgoing fibres (Fig. 40) on reaching the corresponding sympathetic ganglion may behave in a variety of ways. (*a*) They may terminate there and be relayed by non-medullated fibres, which are distributed by sympathetic branches or which pass *via* the grey ramus communicans to the spinal nerve to be distributed to sweat glands, etc. (*b*) They may pass through the ganglion to be relayed in a collateral ganglion (*e.g.* semilunar, Fig. 40). (*c*) They may ascend (or descend) in the gangliated trunk and be relayed in a ganglion at a higher (or lower) level. All the efferent fibres distributed by the cervical sympathetic ascend from T. 1 or T. 2 (Fig. 40), and they are involved, therefore, in complete transverse lesions of the spinal medulla, above the level of the first thoracic segment. Such lesions are accompanied by paralysis of the dilatator pupillæ muscle, which is supplied by fibres which leave the superior cervical ganglion of the sympathetic trunk and enter the skull with the internal carotid artery. As a result of this paralysis, the pupil on the affected side is small and does not react to light.

The paths of the afferent fibres which travel by the sympathetic are not so well known. It is generally believed (1) that all afferent sympathetic fibres have their parent cells in the posterior nerve root ganglia of the spinal nerves, and (2) that afferent sympathetic fibres from the viscera travel by the white rami communicantes (Fig. 40). Nothing definite is known of the subsequent path of afferent sympathetic fibres in the spinal medulla.

The *vaso-constrictor nerves* travel by the sympathetic and are distributed in the first place to the aorta. The rich aortic plexus gives off numerous offshoots to its various branches, and these travel to their destination along the walls of the vessels, lying for the most part in the tunica adventitia. Advantage is taken of the course of the fibres in the operation of *Periarterial Sympathectomy,* which has recently been performed for threatened gangrene and in Raynaud's disease. The operation, which has been performed on the femoral, axillary, and common carotid arteries, consists in the excision of a collar of the tunica adventitia, about an inch long. In this way the vaso-constrictor nerves to the distal part of the artery concerned and its branches are completely interrupted. Care must be taken to remove the adventitia as completely as possible without involving the muscular wall. It is possible that the conflicting results at present obtained may be due, in cases of failure, to incomplete removal of the tunica adventitia.

The *Parasympathetic System* is not an anatomical entity like the Sympathetic System. The term is used to cover certain constituents of some cerebral and some spinal nerves, which are distributed to glands and unstriped muscle, and it is characteristic of the fibres concerned that they are relayed in peripheral ganglia, situated, as a rule, in the walls of the viscera which they innervate. The "cranial" part of the Parasympathetic System travels (1) *via* the oculo-motor nerve (to the sphincter iridis and the ciliary muscle), (2) *via* the facial nerve (and the chorda tympani to the submaxillary and sublingual glands), (3) *via* the glossopharyngeal nerve (to the parotid gland), and (4) *via* the vagus nerve (to the heart, lungs, stomach, etc.).

The sacral part of the Parasympathetic System is formed by the "*pelvic splanchnics*" or "*nervi erigentes*." The fibres arise from S. 2 and S. 3, or S. 3 and S. 4, and pass direct to the pelvic viscera, being relayed in minute ganglia situated on the walls of the viscera concerned.

Referred pains or cutaneous or subcutaneous areas of hyperæsthesia are frequently associated with some pathological condition existing in a viscus. They may be explained on the ground that visceral afferent fibres are brought into relation with cells on the afferent cerebro-spinal path by means of collaterals, either at the posterior nerve root ganglia (Dogiel) or in the posterior column of the grey matter of the spinal medulla. Under normal conditions afferent visceral impulses do not stimulate the cells in the cerebro-spinal path, but they may do so when they become altered, either qualitatively or quantitatively, as the result of some pathological process. (See also p. 246, and cf. Fig. 73.)

The Posterior Triangle of the Neck.—The upper part of the posterior triangle of the neck is exposed during the removal of the postero-superior group of the deep cervical lymph glands; its lower part is exposed (1) in operations on the postero-inferior group of lymph glands, (2) in operations on the brachial plexus, (3) in ligature of the third part of the subclavian artery, and (4) in the removal of a cervical rib. The *base* of the triangle is formed by the middle third of the clavicle, and its *anterior* and *posterior boundaries* by the posterior border of the sterno-mastoid and the anterior border of the trapezius respectively. The layers of fascia which form the roof and cover the floor of the triangle are described on pp. 113, 114. Between them a varying amount of loose fat is found, in which lie the accessory nerve, the descending branches of the cervical plexus, and the termination of the external jugular vein.

The **Accessory Nerve** emerges from the sterno-mastoid at the junction of the upper and middle thirds of its posterior border, and runs obliquely downwards and laterally across the posterior triangle. About two inches above the clavicle, or on a level with the seventh cervical spine, it disappears under cover of the anterior border of the trapezius, in which it terminates. Below, and parallel to the accessory nerve, the branches to the trapezius from C. 3 and C. 4 cross the triangle. In operations in this region they may be mistaken for the accessory nerve, and, as it is important that the latter should be preserved, the surgeon may require to nip the nerve with dissecting forceps to make certain of its identity. When this is done the trapezius muscle will contract and a definite elevation of the point of the shoulder will be produced, owing to the action of the muscle as a rotator of the scapula (p. 6). Both these motor nerves pass to the deep surface of the trapezius, and in this way they can be distinguished from the posterior supra-clavicular (supra-acromial) nerves, which run superficial to the muscle (Fig. 35).

In its lower part the space is crossed by the posterior belly of the omo-hyoid, which runs medially and slightly upwards. Laterally, the muscle is completely hidden by the clavicle, but as it approaches the sterno-mastoid it rises to a higher level. When operating in this region the surgeon often finds it convenient to cut through the fascial sheath of the omo-hyoid (p. 113) so that the muscle may be retracted upwards. If necessary, it may be cut away, without any subsequent disability.

The **Transverse Cervical Artery** arises from the thyreo-cervical trunk (thyreoid axis, p. 147), and runs laterally, deep to the sterno-mastoid, but in front of the prevertebral fascia and the scalenus anterior. It then crosses the floor of the posterior triangle under cover of the posterior belly of the omo-hyoid. In enlargement of the lymph glands in this region the transverse cervical artery is increased in size, and the hæmorrhage which occurs during their removal is due to the division of its branches.

The **Transverse Scapular (Suprascapular) Artery** has a similar origin and course, but it lies at a lower level. It is placed behind the clavicle, and crosses in front of the subclavian artery and the brachial plexus. The veins which accompany these arteries join the external jugular as it lies in front of the third part of the subclavian artery (p. 135).

Exposure of the lower part of the Posterior Triangle.—A *curvilinear incision,* extending downwards along the sterno-mastoid and laterally along the clavicle, gives the best view of the lower part of the posterior triangle. When the flap is turned backwards the external jugular vein is exposed, near the apex of the wound, as it pierces the deep fascia (p. 111).

In order that the important nerves may not be injured, the loose fat which lies on the floor of the triangle is best removed by the finger, covered with gauze.

In exposing the brachial plexus after injuries by gunshot wounds, or in obstetrical paralysis, etc., the sterno-mastoid is drawn forwards and the scalenus anterior is then brought into view. If there is little scar tissue the nerves may be looked for at the lateral border of the scalenus anterior, from behind which they emerge. The prevertebral fascia must be incised, and C. 5 is found about an inch above the posterior belly of the omo-hyoid. But if much scar tissue is present it is easier and safer to look for the supra-scapular nerve first. It will be found by blunt dissection in the angle between the clavicle and the anterior border of the trapezius, and it can then be traced medially to its origin from the upper trunk of the plexus, formed by the union of C. 5 and C. 6.

These nerves can be followed to the point where they emerge from under cover of the scalenus anterior, and the lower nerves of the plexus can then be identified. C. 8 and T. 1 unite to form the lower trunk behind the scalenus anterior. This nerve trunk generally lies just below the omo-hyoid and above the subclavian artery, but sometimes it is found behind the artery, occupying the posterior part of the subclavian groove on the upper surface of the first rib.

An *oblique incision,* running from the junction of the middle and lower thirds of the posterior border of the sterno-mastoid to the angle between the trapezius and the clavicle, may also be used in the exposure of the brachial plexus. If necessary, it may be prolonged across the clavicle, and the bone may be divided temporarily. The external jugular vein is exposed and ligatured, and the omo-hyoid is freed and retracted upwards or downwards.

Bilateral Ulnar Paresis and Analgesia sometimes supervene if a person, who usually sleeps on one or other side, falls asleep lying on his back. The explanation is to be found in the close relationship between the first thoracic nerve (or the lower trunk) and the first rib, for the weight of the shoulders falling backwards is sufficient to cause pressure on the nerve. For a similar reason, symptoms resembling those produced by a cervical rib (p. 102) may occur in patients who are restricted to a dorsal decubitus after abdominal operations, or if the arms have been allowed to hang down unsupported from the operating table. Further, recent observations have shown that symptoms ascribed to the presence of a cervical rib may in reality be due to the first (thoracic) rib. Moreover, the first rib has been partially removed in some cases, with complete disappearance of the symptoms.

Cervical Rib.—The ventral portion of the transverse process of a cervical vertebra is homologous with a thoracic rib, and is termed the *costal* element. In the case of the sixth and seventh cervical vertebræ the costal elements frequently develop from independent secondary centres of ossification, and occasionally they undergo abnormal development so as to form cervical ribs. The condition may be unilateral or bilateral, and varies from a simple exostosis of the costal element to a fully formed rib, articulating, by complete joints, with the transverse process and body of the seventh cervical vertebra. The ventral extremity of the rib may reach the sternum, or it may articulate or fuse with

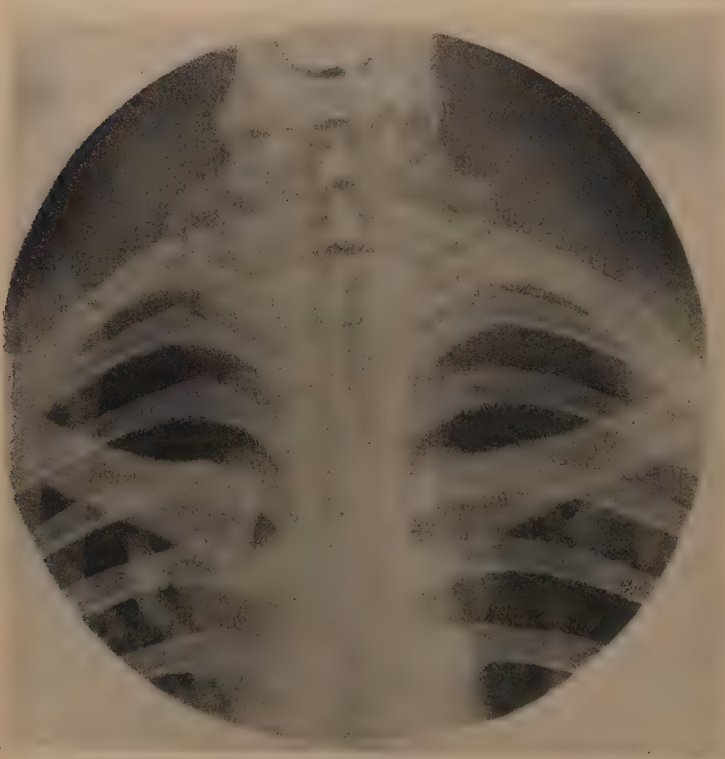


FIG. 41.—Bilateral Cervical Ribs. Viewed from behind. The cervical ribs are considerably foreshortened.

the first thoracic rib; when small, it may be attached to the first thoracic rib by a fibrous band, or it may present a free extremity. Radiograms, taken in an antero-posterior plane, frequently fail to show a cervical rib when one is present, owing to foreshortening consequent on its downward and forward direction.

When the rib is well developed, both the subclavian artery and the lower trunk of the brachial plexus groove its upper and anterior surface. In these cases the artery occupies a higher position than normal, and its pulsations are readily felt. The diagnosis of aneurism may suggest itself, especially as the radial pulse on the affected side is weakened, but *this sign disappears when the limb is elevated.* Very often the rib is too short to support the artery, and is crossed by the nerve trunk only. Even in these cases the artery lies at a higher level than normal.

Muscular attachments are determined by the size of the rib. When it is complete, or nearly so, it receives the insertions of the scalenus anterior and the scalenus medius, and intercostal muscles occupy the space between it and the first thoracic rib.

A cervical rib may be present without causing any symptoms. Frequently, however, the pressure on the lower trunk of the brachial plexus is such that the removal of the rib must be undertaken. The nervous symptoms are described on p. 102.

Removal of a Cervical Rib.—In this operation it is important that the whole area should be widely exposed. This can be effected by a curvi-linear incision passing down the posterior border of the sterno-mastoid and turning laterally along the clavicle. The external jugular vein is secured as it pierces the deep fascia, and the posterior belly of the omo-hyoid is removed. The fat and lymph glands which lie on the floor of the posterior triangle are dissected away, and the prevertebral fascia is exposed. At this stage the dorsalis scapulæ nerve (to the rhomboids) and the long thoracic nerve (of Bell) (p. 135) are secured and traced up to their point of exit from the scalenus medius. They are then retracted to one or other side, and the lateral or posterior border of the scalenus medius is defined. The rest of the operation is carried out behind the muscle, and in this way the brachial plexus and the subclavian artery, which are displaced forwards, need not be exposed. The scalenus medius is next separated from the upper surface of the rib in a forward direction, and the bone is divided as close to its proximal extremity as possible. The distal portion is drawn laterally, and separated from the intercostal muscles. It is then traced forwards as far as possible and again divided.

The same method may be adopted in the removal of a first thoracic rib, if it is producing pressure symptoms, but great care must be exercised to avoid injuring the pleura.

The **Muscular Floor of the Posterior Triangle** is formed in its upper part by the *splenius capitis*, the fibres of which pass forwards and upwards from the vertebral spines and ascend under cover of the upper part of the sterno-mastoid to reach the mastoid process. Below and parallel to the splenius capitis, the *levator scapulæ* (Fig. 42) runs downwards and laterally from the transverse processes of the upper cervical vertebræ to reach the medial (superior) angle of the scapula. At a lower level the *scalenus medius* and *posterior* form the floor of the triangle. They are usually more or less blended with one another, and their fibres have a more downward inclination, as they are inserted into the posterior portions of the first and second ribs respectively. In their lower part they are crossed by the trunks of the brachial plexus and the subclavian artery.

The **Scalenus Anterior** is usually completely under cover of the posterior border of the sterno-mastoid, but it is exposed when that muscle is retracted medially. It arises from the anterior tubercles of the transverse processes of the intermediate cervical vertebræ, and runs downwards and slightly laterally, to be inserted into the scalene tubercle on the inner margin of the first rib. Like the muscles in the floor of the posterior triangle, it lies behind the prevertebral fascia, by which it is separated from the posterior belly of the omo-hyoid.

The **Phrenic Nerve** arises mainly from C. 4, but it usually receives additional fibres from C. 3 and C. 5. It runs vertically downwards in front of the scalenus anterior but behind the prevertebral fascia, and it is overlapped by the internal jugular vein. Owing to the obliquity of the muscle, the phrenic nerve crosses the scalenus anterior from its lateral to its medial border (Fig. 44).

The *nerves of supply* to the levator scapulæ and the scalene muscles all lie deep to the prevertebral fascia (p. 113).

The **Dorsalis Scapulæ Nerve (N. to the Rhomboids)** arises from C. 5, as it lies between the scalenus anterior and medius, and passes backwards through the scalenus medius, emerging on its lateral surface, under cover of the posterior belly of the omo-hyoid. It disappears by passing between the levator scapulæ and the scalenus posterior.

The **Long Thoracic Nerve (of Bell)** arises by three roots, from C. 5, 6, and 7. The first root arises in common with the dorsalis scapulæ nerve, but separates from it in the scalenus medius and appears on the surface of the muscle at a slightly lower level. The second root also pierces the scalenus medius, and unites with the first to form a common trunk, which runs downwards to the axilla behind the main part of the plexus. The root from C. 7 arises near the lateral border of the scalenus medius, and enters the axilla before uniting with the rest of the nerve (p. 99).

Both the dorsalis scapulæ and the long thoracic nerves lie behind the prevertebral fascia, and, in removal of the postero-inferior group of the deep cervical lymph glands, they are in no danger so long as the fascia is not disturbed. In operations in which the prevertebral fascia requires to be opened, *e.g.* repair of brachial plexus, these two nerves should be found and isolated as soon as the fascia is incised.

The **Third Part of the Subclavian Artery** commences at the lateral border of the scalenus anterior, and extends downwards and laterally to the outer border of the first rib. Near its termination, the artery lies completely behind the clavicle. If pressure is exerted in a downward, medial, and backward direction in the angle between the posterior border of the sternomastoid and the clavicle, the subclavian artery can be compressed against the first rib.

In making the *incision* for the purpose of *ligaturing* this part of the subclavian artery, the surgeon draws the skin down over the clavicle and incises it along the bone. When the skin is allowed to retract upwards, the deep fascia, which cannot be drawn down with it, is found exposed but not incised, and therefore there is no risk of injury to the underlying veins in making the incision. After division of the deep fascia, the external jugular vein is found as it crosses the artery to join the subclavian vein. It receives the transverse cervical and transverse scapular (supra-scapular) veins from the lateral side, and these vessels, though often very large, must not be mistaken for the subclavian vein, which lies at a lower level and is under cover of the clavicle. The posterior belly of the omo-hyoid is freed and retracted upwards, and the veins, referred to above, are ligatured. In this process the transverse scapular (supra-scapular) artery (p. 130) is exposed and pulled aside. The brachial plexus lies above and to the lateral side of the subclavian artery, and especial care must be taken to avoid injuring the lower trunk, which frequently lies behind the vessel. By retracting the sterno-mastoid medially, the lateral border of the scalenus anterior, which forms an important landmark, is brought into view. If the finger is carried downwards along this border till the tip rests on the *scalene tubercle*, the pulp of the finger can feel the pulsations of the artery. As the ligature is applied close to the lateral border of the scalenus anterior, great care must be taken lest the pleura, which lies behind the second part of the artery, be damaged.

In **Interscapulo-Thoracic Amputation** the clavicle is divided, or its middle third is resected and the subclavius muscle is removed. This enables the surgeon to ligate the subclavian artery and vein and to cocainise the trunks of the brachial plexus.

The **Deep Cervical Lymph Glands** lie mainly under cover of the sterno-mastoid, but they project partly into the anterior and partly into the posterior triangle. They can be subdivided into four groups, upper and lower posterior and upper and lower anterior (Stiles).

1. The **Upper Posterior Group** lies on the roots of the cervical plexus and extends into the posterior triangle. They receive afferents from the pharynx, the occipital, and the mastoid lymph glands, and from the upper anterior group. When these glands are enlarged, the accessory nerve may be found embedded in their midst, or lying immediately under the investing layer of the deep cervical fascia, on the surface of the glandular mass.

2. The **Lower Posterior Group** lies in relation to the posterior belly of the omo-hyoid and *superficial to the prevertebral fascia.* They may be involved alone in ascending infection from the axillary glands, as in malignant disease, or they may be attacked by a descending infection from the upper groups, or by a lateral spread from the lower anterior group.

3. The **Upper Anterior Group** is situated around the upper part of the carotid sheath, but a few of the glands lie within the sheath in close contact with the internal jugular vein. They receive afferents from the interior of the cranium, the pharynx, mouth, nose, upper part of larynx, etc., either directly, or indirectly from the submental and submaxillary lymph glands.

The tonsillar lymph gland is placed in the angle between the common facial and the internal jugular veins. It is very constant in position, and is very early involved in tuberculous disease (p. 193). It receives afferents directly from the palatine tonsil.

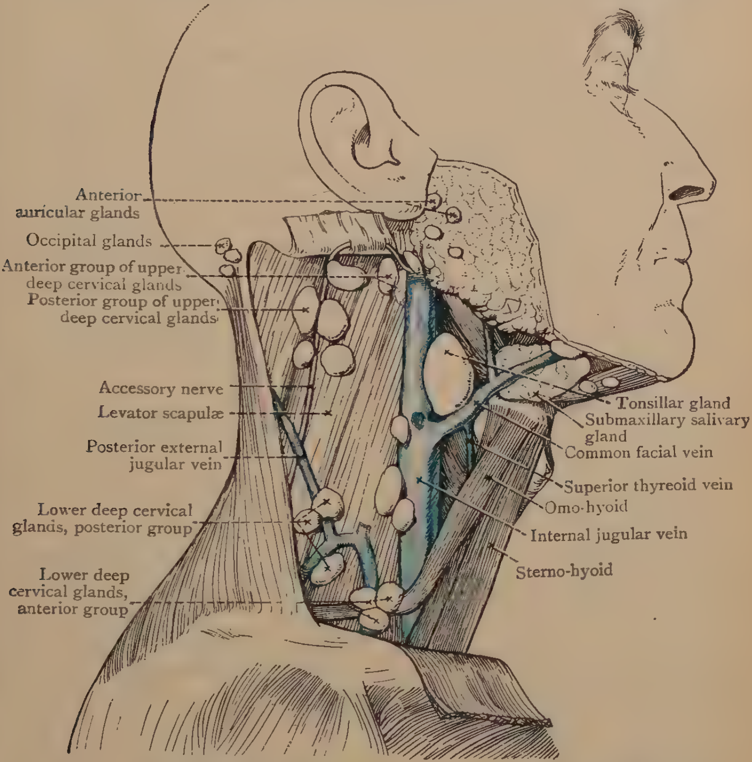

Anterior auricular glands
Occipital glands
Anterior group of upper deep cervical glands
Posterior group of upper deep cervical glands
Accessory nerve
Levator scapulæ
Posterior external jugular vein
Lower deep cervical glands, posterior group
Lower deep cervical glands, anterior group
Tonsillar gland
Submaxillary salivary gland
Common facial vein
Superior thyreoid vein
Omo-hyoid
Internal jugular vein
Sterno-hyoid

FIG. 42.—The Veins and Lymph Glands of the Neck. The upper part of the external jugular vein has been resected. The sterno-mastoid has been cut across below the point at which it is pierced by the accessory nerve, and the two cut ends have been turned upwards and downwards, respectively.

4. The **Lower Anterior Group** lies in relation to the lower part of the carotid sheath and the scalenus anterior. Some of the members of this group are placed within the sheath; others lie between the scalenus anterior and the cervical pleura; and

the remainder are in contact with the anterior surface of the muscle. They may be infected secondarily to the upper anterior and lower posterior groups, or they may be alone involved following ascending infection from the mediastinal lymph glands.

Surgical Approach to the Deep Cervical Lymph Glands.—If, *when the upper group is involved*, the enlarged lymph glands do not extend into the posterior triangle, an oblique *incision* running downwards and forwards in the skin creases of the neck, towards the laryngeal prominence, may be utilised. It should not approach nearer than one finger's breadth to the angle of the mandible, lest the cervical branch of the facial nerve be cut, with subsequent paralysis of the muscles of the lower lip (p. 110).

If the enlarged glands extend far into the posterior triangle an *inverted* J*-shaped incision* (Stiles) gives the best access. Starting near the greater cornu of the hyoid, it passes obliquely upwards towards the mastoid process and is then carried downwards along the anterior border of the trapezius. The latter part of the incision may be carried as far as the clavicle, if necessary, and, as it passes through the investing layer of the deep cervical fascia, care must be taken to avoid injuring the accessory nerve (p. 129).

In both cases the external jugular vein is liable to injury. It is exposed when the margins of the oblique incision are undercut, or when the curved flap, which includes the platysma, is turned downwards. It is advisable to secure the vein at once, as high up and as low down as possible. The intervening portion can then be removed, usually together with the great auricular nerve (p. 110). Excessive bleeding at this stage is suggestive of glandular pressure on the internal jugular vein, with consequent engorgement of the collateral channels of venous return. In the subsequent stages of the operation the structures most liable to injury are the internal jugular vein and the accessory nerve. They are therefore identified as soon as the skin flaps, along with the investing layer of the deep fascia, have been undermined and retracted. In tuberculous lymph-adenitis the caseous glands are commonly adherent to the carotid sheath, and this structure should be incised below the diseased area. The internal jugular vein can then be dissected free without injury, while the caseous glands and the adherent sheath can be removed. In malignant disease, however, the vein and sometimes the artery have to be sacrificed. When ligatures are being applied, prior to resection, care must be taken not to include the vagus nerve. Should the common facial vein be wounded near its termination, the hæmorrhage may be so great, owing to its proximity to the internal jugular, as to suggest injury of the larger vessel. In ligation of the common facial, the ligatures must be placed so as to control its numerous tributaries (superior thyreoid, etc., p. 121).

The accessory nerve is found in the upper part of its course by dissecting the deep fascia off the anterior border of the sterno-mastoid, 1½ inches below the tip of the mastoid process. It pierces this fascia to reach the muscle. The branch from the occipital artery to the sterno-mastoid (p. 124) serves as a convenient guide, and, after the nerve has been found in this situation, it is traced upwards and forwards through the glands till it disappears under cover of the posterior belly of the digastric (p. 125). Improved access to the highest group of lymph glands, which lie under cover of the parotid gland and the mastoid process, may be obtained by dividing the anterior part of the insertion of the sterno-mastoid transversely. These lymph glands lie superficial to, and slightly lower than, the occipital artery.

The position of the accessory nerve in the posterior triangle of the neck is described on p. 129. *When the lymph glands of the posterior triangle are involved*, the nerve must be exposed before they are attacked, as it is the most important structure in the region. If a little dissection amongst the enlarged glands above the middle of the posterior border of the sterno-mastoid fails to expose the nerve, it must be sought for at the point where it disappears under cover of the trapezius (p. 129), and then traced upwards through the mass. The enlarged glands are apt to alter the course of the nerve, and it runs grave risk of injury if a prolonged search for it is made amongst them.

When the lower groups are involved, good exposure is obtained by a long oblique incision extending from the junction of the middle and lower thirds of the anterior border of the trapezius almost to the jugular (suprasternal) notch. The terminal part of the external jugular vein and the accessory nerve are exposed,—the latter as it disappears under cover of the trapezius in the posterior part of the wound. In removing the glands, the surgeon does not require to cut through the prevertebral fascia, and, as a result, the nerves of supply to the levator scapulæ and the rhomboids, the phrenic nerve and the long thoracic nerve (of Bell)—which all lie behind the fascial sheet—are perfectly safe. When the glands are being dissected from under the posterior belly of the omo-hyoid, hæmorrhage may occur from the enlarged branches of the transverse cervical artery which supply them.

The removal of the lower anterior group of lymph glands is fully described on p. 145.

When all the deep cervical lymph glands are involved, the large inverted J-shaped incision (p. 138) may be utilised, or it may be converted into an inverted U. This operation is greatly simplified by dividing the sterno-mastoid transversely below the level of the accessory nerve and turning the cut ends upwards and downwards. The internal jugular vein and the accessory nerve are satisfactorily exposed by this procedure. Behind the prevertebral fascia, the ascending cervical artery, which is a branch of the inferior thyreoid, runs upwards in front of the scalenus anterior on the medial side of the phrenic nerve and gives numerous branches to the deep cervical lymph glands.

Posterior Aspect of Neck.—This region of the neck is exposed by the surgeon in the operation for the division of the posterior rami (primary divisions) of the cervical nerves, a proceeding which is called for in certain cases of *Spasmodic Torticollis*. A vertical incision is made from a point midway between the mastoid process and the external occipital protuberance downwards to the level of the superior border of the scapula. The line of this incision overlies the posterior triangle of the neck above and the trapezius below. After the skin and fasciæ have been incised and undercut on each side, the splenius is exposed in the upper part of the wound and can be recognised by the direction of its fibres, which run upwards and laterally. In the lower part of the wound the splenius is covered over by the trapezius. The latter muscle is cut through in the line of the original incision and dissected off the surface of the lower part of the splenius. The whole of the splenius is next divided in the same line, and the two parts of the muscle are undermined and retracted. The longissimus capitis (trachelo-mastoid), which is a thin muscular sheet closely applied to the deep surface of the splenius, is usually retracted along with the lateral part of the muscle. When this is the case, the vertical fibres of the semispinalis capitis (complexus) are completely exposed, with the superficial branches of the ramus descendens of the occipital artery and their venæ comites on its surface. The semispinalis capitis is split along the whole length of the incision, and the two parts are undermined and retracted. The deep branch of the ramus descendens and the numerous veins which accompany it should now be secured. They are found running downwards on the deep surface of the semispinalis capitis (complexus), and the arteria profunda cervicis, which ascends between the same muscular layers to anastomose with the ramus descendens (p. 122), may also be controlled at this stage. The semispinalis cervicis (colli) is now exposed in the lower part of the wound,

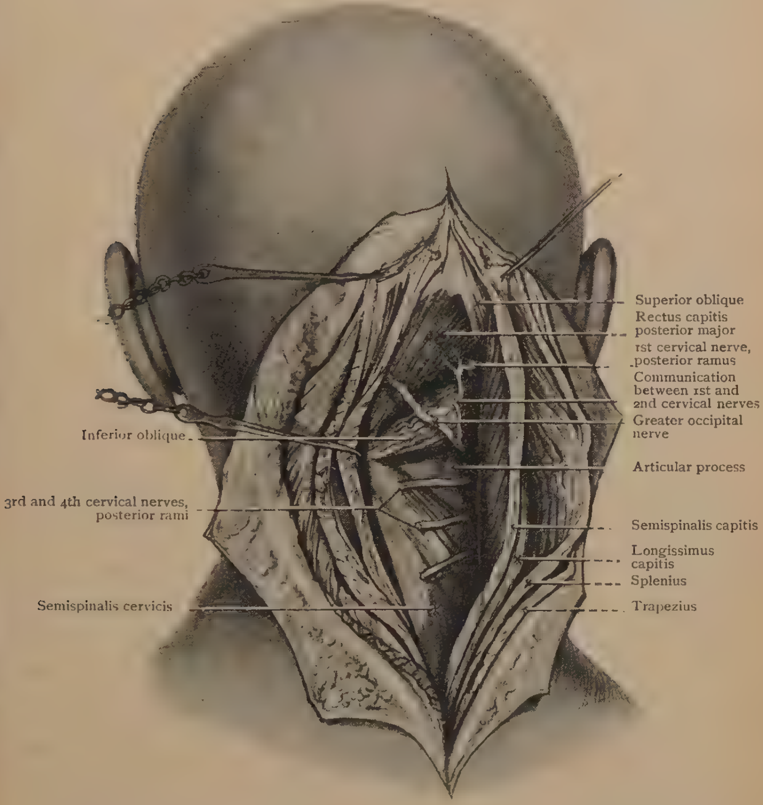

Superior oblique
Rectus capitis posterior major
1st cervical nerve, posterior ramus
Communication between 1st and 2nd cervical nerves
Greater occipital nerve
Articular process
Semispinalis capitis
Longissimus capitis
Splenius
Trapezius
Inferior oblique
3rd and 4th cervical nerves, posterior rami
Semispinalis cervicis

FIG. 43.—Exposure of the Posterior Rami (Primary Divisions) of the Upper Cervical Nerves.

and its fibres can be seen extending upwards to the spine of the second cervical vertebra. Along its lateral border the articular processes of the cervical vertebræ can be made out, while the muscular sub-occipital triangle is exposed in the upper part of the incision (Fig. 43).

The lower boundary of the *sub-occipital triangle* is formed by the inferior oblique, which extends from the spine of the second cervical vertebra to the transverse process of the atlas. The medial boundary, formed by the rectus capitis posterior major, extends from the spine of the second cervical vertebra upwards to the occipital bone; and the lateral boundary, formed by the superior oblique, ascends from the transverse process of the atlas to the occipital bone. The floor of the triangle is formed by the posterior arch of the atlas and the posterior atlanto-occipital membrane (ligament). The vertebral artery lies on the lateral part of the floor. After leaving the foramen in the transverse process of the atlas, it bends round the posterior aspect of the lateral mass prior to piercing the posterior atlanto-occipital membrane and the dura mater. In this part of its course the artery is separated from the posterior arch of the atlas by the posterior ramus (primary division) of the first cervical nerve, which at once breaks up into small branches to supply the surrounding muscles.

The most important landmark at this stage is the *greater occipital nerve*. It emerges at the lower border of the inferior oblique and at once turns upwards and medially into the retracted flap (Fig. 43). At the lower border of the inferior oblique the greater occipital nerve gives off a communicating branch, which enters the sub-occipital triangle and joins the first cervical nerve. It is essential that this branch should be found and traced, as in this way the first cervical nerve can be found with a minimum of risk to the vertebral artery. The first cervical and the greater occipital nerves—the latter represents the posterior ramus (primary division) of C. 2—are cut away as close to their origins as possible.

The lower nerves are embedded in the fascia which separates the semispinalis capitis (complexus) from the semispinalis cervicis. If this fascia is left behind when the former muscle is undermined, the nerves will be found on the surface of the latter (Fig. 43); if not, they will be found on the deep surface of the semispinalis capitis. They should be traced to the lateral border of the semispinalis capitis and there cut away, close to the articular processes.

The Deep Triangle of the Neck is a well-defined region which is of great importance to the surgeon, more especially on the left side. It lies behind the lower part of the carotid sheath and is bounded medially by the longus colli and laterally by the scalenus anterior. The two muscles converge above on the transverse process of the sixth cervical vertebra to form the apex of the triangle, while, inferiorly, the space is bounded by the first part of the subclavian artery. The surgeon deals with this region (1) in operations for ligature of the vertebral artery, (2) in œsophagotomy, (3) in excision of œsophageal diverticula, and (4) in the removal of the lower anterior group of the deep cervical lymph glands.

In the first three operations mentioned, access is obtained by an incision along the anterior border of the sterno-mastoid. After the investing layer of the deep cervical fascia has been cut through, the muscle is retracted to the lateral side, or its sternal head may be divided. The sterno-hyoid and sterno-thyreoid muscles are retracted medially and the pretracheal fascia is incised to the medial side of the carotid sheath, which is then retracted laterally. In this way the posterior part of the lateral lobe of the thyreoid gland is exposed behind the margin of the sterno-thyreoid. The subsequent procedure differs in the various operations.

(*a*) *Œsophagotomy*.—The œsophagus projects slightly to the left side from behind the trachea. In the groove between them, the left recurrent (laryngeal) nerve passes upwards to disappear at the lower border of the inferior constrictor, and the descending limb of the inferior thyreoid artery (Fig. 44) runs downwards to reach the lower pole of the thyreoid gland. The muscular wall of the œsophagus may be fully exposed by retracting the trachea, the thyreoid gland, and the depressor muscles of the hyoid bone, to the right. Posteriorly, the œsophagus rests on the longus colli, in a layer of loose cellular tissue, but it can easily be freed from the muscle and raised to the surface. The mucous and submucous coats of the œsophagus are only attached to the muscular coat by loose areolar tissue, and hence the tube is very distensible. In performing œsophagotomy, therefore, care must be taken not to work round in the interval between the coats and so open the muscular coat on the opposite side in mistake for the mucous coat. To prevent this mishap, an œsophageal bougie may be passed and cut down upon at this stage of the operation.

(*b*) *Excision of Œsophageal Diverticula*.—These diverticula generally occur on the left side, and they occupy the interval between the œsophagus and the carotid sheath, which is thus displaced to the lateral side. The entrance to the diverticulum lies opposite the sixth cervical vertebra, *i.e.* at the point where the pharynx and œsophagus are continuous. After excision of the diverticulum, the œsophageal wound is closed horizontally to avoid the formation of a stricture.

In both of these œsophageal operations a drainage tube is inserted to prevent any septic infection passing down into the thorax along the carotid sheath.

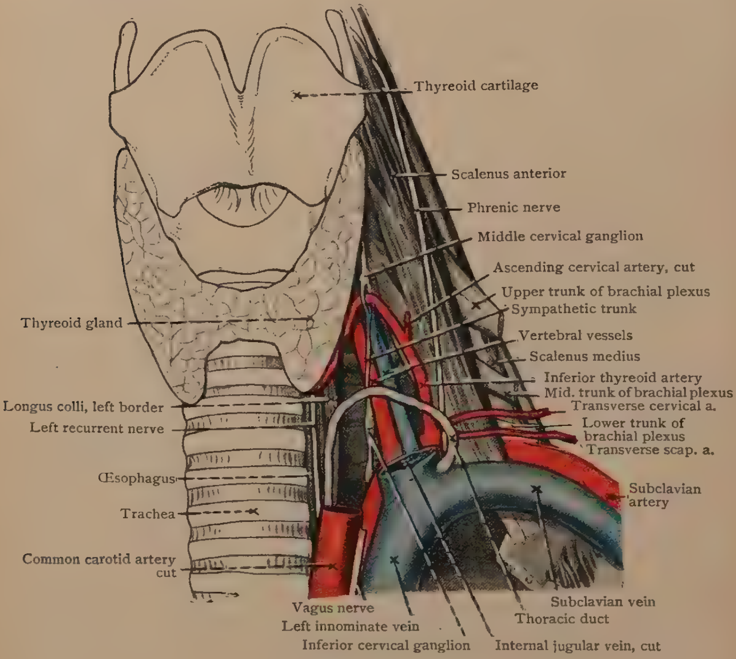

Thyreoid cartilage
Scalenus anterior
Phrenic nerve
Middle cervical ganglion
Ascending cervical artery, cut
Upper trunk of brachial plexus
Sympathetic trunk
Vertebral vessels
Scalenus medius
Inferior thyreoid artery
Mid. trunk of brachial plexus
Transverse cervical a.
Lower trunk of brachial plexus
Transverse scap. a.
Subclavian artery
Thyreoid gland
Longus colli, left border
Left recurrent nerve
Œsophagus
Trachea
Common carotid artery cut
Vagus nerve
Left innominate vein
Inferior cervical ganglion
Subclavian vein
Thoracic duct
Internal jugular vein, cut

FIG. 44.—The Deep Triangle of the Neck.

(*c*) *Ligature of the Vertebral Artery.*—In this operation the deep triangle of the neck is more fully exposed. The vertebral artery arises from the first part of the subclavian and runs upwards and backwards behind the carotid sheath. It disappears from view at the apex of the triangle by entering the foramen in the transverse process of the sixth cervical vertebra. Shortly before it disappears it is crossed anteriorly by the inferior thyreoid artery and, on the left side, at a lower level by the thoracic duct (Fig. 44). From both of these structures it is usually separated by its companion vein, which runs downwards in front of it and crosses the subclavian artery to terminate in the innominate vein. In order to avoid the inferior thyreoid artery and the thoracic duct, the surgeon applies the ligature as close as possible to the transverse process of the sixth cervical vertebra, which forms the most important guide to the vertebral artery. It may be necessary to tie the vertebral vein before the artery is ligatured, and it may be impossible to avoid including some fibres of the cervical sympathetic, which emerges from the posterior wall of the carotid sheath in the lower part of the neck.

(*d*) In *removal of the lower anterior group of the deep cervical lymph glands* good access is essential, and it is obtained by the oblique (p. 139) or curvi-linear (p. 130) incision already described.

The external jugular vein is exposed and a portion of it is resected between ligatures. The fascial sheath of the sterno-mastoid is opened, and the muscle is divided about an inch or more above the clavicle, and the two cut ends are widely retracted. This procedure exposes the carotid sheath medially and, to its lateral side, the scalenus anterior, with the phrenic nerve and the posterior belly of the omo-hyoid on its surface. The ascending cervical artery, which supplies many of the glands of this group, lies close to the medial side of the phrenic nerve. In order to avoid injuring the phrenic nerve and, on the left side, the thoracic duct, the glands are best removed by the finger covered with gauze, but if the knife is used great care must be exercised. In an old-standing case, where the glands have become caseous, the scalenus anterior—and even the sterno-mastoid—may be partially destroyed, and the phrenic nerve is then more liable to injury.

If the lower anterior group is the *only* group affected in the neck, the enlargement is probably due to an ascending infection from the bronchial lymph glands. As the disease spreads upwards along the blood-vessels, the lymph glands which lie along the lower part of the carotid sheath are the first to be involved. Consequently these glands show a more advanced stage of the disease than the glands lying along the lateral border of the scalenus anterior, which will not present the same number of caseous foci. On the other hand, in descending infections, the higher glands of the group are the first to be involved, and the lower glands always show a less advanced stage of the disease.

The **Thoracic Duct** is closely applied to the left side of the œsophagus, as it leaves the thorax. It ascends into the neck for an inch or sometimes an inch and a half above the clavicle, and then turns laterally behind the carotid sheath and its contents, but in front of the vertebral and the inferior thyreoid arteries. It usually crosses in front of the vertebral vein, but in many cases it passes behind that vessel. On reaching the medial border of the scalenus anterior, the thoracic duct passes downwards to enter the postero-lateral aspect of the union of the subclavian and internal jugular veins of the left side. Sometimes it extends farther laterally on to the surface of the scalenus anterior, and it usually crosses the phrenic nerve. As it lies behind the carotid sheath the duct crosses the deep triangle (Fig. 44), where it lies above the level of the first part of the subclavian artery. Near its termination the thoracic duct lies in front of the big vessel. It may terminate as a single trunk, or it may break up into a number of small branches, which join the internal jugular and subclavian veins independently of one another. If the duct is injured, its ends must be ligatured if it is impossible to reunite them.

The thoracic duct drains the lymph from both lower limbs, the abdominal walls and most of the abdominal viscera, and the left half of the thorax. In addition it is joined near its termination by the subclavian trunk, from the left upper limb, and the jugular trunk, from the left side of the head and neck. These two trunks, however, may end independently in the subclavian and internal jugular veins respectively.

The **Subclavian Artery** arises, on the right side, from the innominate artery behind the sterno-clavicular joint, and it arches upwards and laterally, disappearing behind the scalenus anterior. On the left side, it arises within the thorax from the arch of the aorta, and it lies behind the left common carotid artery as it enters the neck. The first part of the artery rests on the cervical pleura, and extends as far as the medial border of the scalenus anterior. It forms the oblique lower border of the deep triangle of the neck, and is covered in front by the internal jugular vein and the vagus nerve. On the right side the recurrent nerve arises from the vagus as it crosses the vessel, and it runs upwards and medially deep to the subclavian and common carotid arteries. A detailed description of the relations of this part of the subclavian artery is unnecessary, as it is rarely ligated by the surgeon.

The **Thyreo-Cervical Trunk (Thyroid Axis)** arises from the subclavian at the medial border of the scalenus anterior, and at once divides into the transverse scapular (suprascapular) (p. 130), the transverse cervical (p. 130), and the inferior thyreoid arteries.

The **Inferior Thyreoid Artery** runs upwards along the medial border of the scalenus anterior and behind the carotid sheath (internal jugular vein). On the left side, the artery is crossed by the thoracic duct close to its origin. A little below the sixth cervical vertebra it turns medially behind the sheath and, at the point where it makes the bend, it gives off the ascending cervical artery (Fig. 44). It crosses in front of the vertebral vein and artery, and at the lateral border of the longus colli it turns downwards and runs in the groove between the trachea and the œsophagus, overlapped by the lateral lobe of the thyreoid gland. At the lower pole of the gland, the artery crosses the recurrent (laryngeal) nerve (p. 172). The vessel may require to be ligated in operations on the thyreoid gland, œsophagus, and larynx.

The first part of the subclavian artery also gives off the vertebral (p. 144) and the internal mammary arteries (p. 509).

The Submaxillary Region of the neck extends upwards, under cover of the mandible, to the mylo-hyoid line and downwards to the hyoid bone. Its *roof* is formed by the deep surface of the mandible and by the investing layer of the deep cervical fascia, which is attached to the lower border of the mandible above and to the hyoid bone below. In front and behind it is bounded by the bellies of the digastric, and the fascial roof blends with the fascial sheath of the muscle, so that a collection of pus in this neighbourhood is definitely circumscribed. The submaxillary salivary gland and numerous *lymph glands*, which extend from the anterior belly of the digastric in front to the mandibular angle behind, occupy the area, and during their examination the head should be flexed in order to relax the strong fascial roof. The surgeon stands behind the patient and inserts the tips of his fingers beneath the lower border of the mandible. By pressing laterally against the bone, he is enabled to detect even a slight enlargement of the anterior group of lymph glands. The more superficial glands of the posterior group, which are intimately related to the submaxillary salivary gland, may be identified near the angle of the mandible if they become enlarged.

The *floor of the space* is formed by the mylo-hyoid in front and above, by the hyo-glossus below and behind, and by the middle and superior constrictors of the pharynx, which appear in the small interval between the posterior belly of the digastric and the posterior border of the hyo-glossus. These muscles are useful surgical landmarks, as they can be readily recognised by the direction of their fibres.

The *mylo-hyoid muscle* arises from the mylo-hyoid line on the deep surface of the mandible, and its fibres run downwards and medially. The posterior fibres reach the hyoid bone, but the anterior fibres are inserted into a fibrous raphe, which extends from the chin to the hyoid bone in the median plane. The *nerve to the mylo-hyoid*, which is a branch from the inferior alveolar (inferior dental) (p. 187), lies on the superficial aspect of the muscle close to its origin. The mylo-hyoid may act as an elevator of the hyoid bone, or, when that bone is fixed, as a depressor of the mandible.

The *posterior belly of the digastric* arises from the temporal bone under cover of the mastoid process. It runs downwards, medially, and forwards towards the greater cornu of the hyoid bone. It crosses the internal jugular vein, the internal and external carotid arteries, the tenth, eleventh, and twelfth cerebral nerves, etc., and it is therefore a most important landmark for the surgeon. It ends in the intermediate tendon, which is bound down to the greater cornu of the hyoid bone by a slip of deep fascia. The posterior belly of the digastric is supplied by the *facial nerve*, which emerges from the stylo-mastoid foramen close to the origin of the muscle.

The *anterior belly of the digastric* passes upwards, forwards, and medially from the intermediate tendon, and is attached to the digastric fossa of the mandible. It is placed on the superficial aspect of the mylo-hyoid muscle, and is supplied by the *mylo-hyoid nerve*.

The digastric muscle may act as an elevator of the hyoid bone, or, if that bone is fixed, as a depressor of the mandible.

The *hyo-glossus*, which lies partly under cover of the mylo-hyoid, arises from the hyoid bone, and its fibres run vertically upwards, medial to the mandible, forming the lateral surface of the tongue. The origin of the hyo-glossus extends farther back on the hyoid bone than the insertion of the mylo-hyoid, and, in consequence, its posterior part can be seen in the angular interval between the greater cornu of the hyoid bone and the oblique posterior border of the mylo-hyoid muscle. It is supplied by the *hypoglossal nerve*.

The *constrictor muscles* (p. 194) have their fibres directed almost horizontally as they lie in this region.

The **Submaxillary Salivary Gland** is situated immediately under the deep fascia and occupies nearly the whole space. It lies on the mylo-hyoid in front, but posteriorly it rests on the hyo-glossus, and part of it passes forwards deep to the oblique posterior border of the mylo-hyoid. It is a soft, lobulated structure of a pinkish colour, and its lobules may be mistaken for lymph glands, some of which lie on its superficial aspect. The *submaxillary duct* (*of Wharton*) emerges from the deep part of the gland and runs forwards, on the upper part of the hyo-glossus and under cover of the mylo-hyoid, to open into the floor of the mouth on a small papilla at the side of the frenulum linguæ. Between the same muscular layers lie the lingual nerve above, and the hypoglossal nerve and its accompanying (ranine) vein below. Both nerves at first run horizontally forwards.

The **Lingual Artery** lies on a deeper plane in this part of its course. On entering the submaxillary region the vessel is placed deep to the stylo-hyoid and the posterior belly of the digastric, and it passes under cover of the posterior border of the hyo-glossus. It then runs forwards horizontally just above the hyoid bone, giving off its *dorsales linguæ branches*, which reach the tongue by passing upwards and sinking into the genioglossus muscle. A *curved incision* is employed to expose the artery. It begins just below the chin, has its mid-point at the greater cornu of the hyoid bone, and extends to near the angle of the mandible. It is carried down through the deep fascia, and the submaxillary gland is then retracted upwards with the flap. The various muscles are identified by the direction of their fibres (*vide supra*), and the hypoglossal nerve is exposed lying on the hyo-glossus in the angular interval between the two bellies of the digastric. In the cadaver the fascial slip which binds the intermediate tendon of the digastric to the hyoid becomes stretched if the head has been extended for any length of time, and the tendon is carried upwards, covering the hypoglossal nerve. The hyo-glossus is cut through parallel to and below the nerve (a quarter of an inch above the hyoid in the cadaver). In life its fibres retract upwards and downwards and leave the lingual artery exposed, lying on the genio-glossus.

Acute inflammatory conditions in the submaxillary region usually arise in connection with the teeth. The pus from an alveolar abscess may make its way through the periosteum, either above or below the attachment of the deep fascia to the mandible (Fig. 45). In the former case it comes to the surface after perforating the platysma, but in the latter case it enters the submaxillary region and gives rise to a cellulitic condition under the deep fascia. Although at first strictly circumscribed, if not released the pus may follow the course of the lingual artery or hypoglossal nerve, and, coming into contact with the carotid sheath, it may give rise to a spreading cellulitis of the neck (*Ludwig's angina*). These abscesses should be opened by Hilton's method in order to avoid injuring the important structures in this neighbourhood.

The **Submaxillary Lymph Glands** may be divided into two groups:

(*a*) The *anterior group* lies in the anterior part of the space, between the mylo-hyoid and the deep surface of the mandible. They receive afferents from the anterior part of the tongue and floor of the mouth, from the lower lip and teeth of the lower jaw, and from the submental lymph glands.

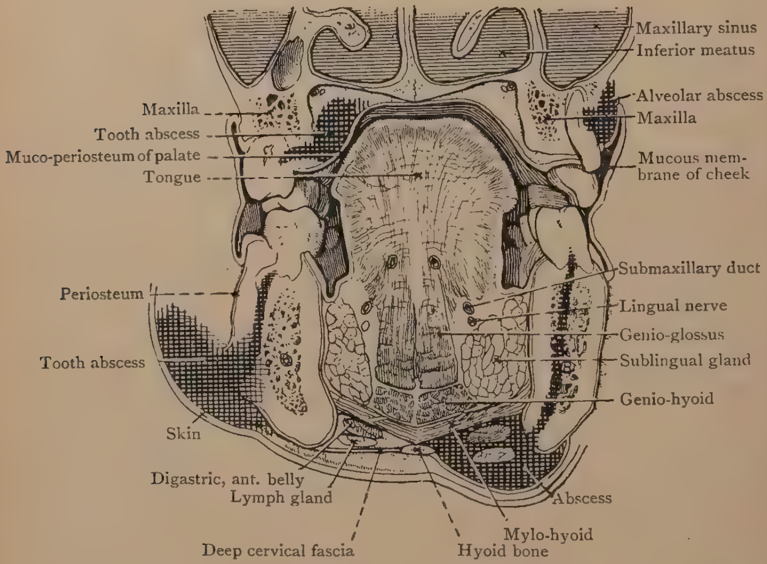

Maxillary sinus
Inferior meatus
Alveolar abscess
Maxilla
Mucous membrane of cheek
Maxilla
Tooth abscess
Muco-periosteum of palate
Tongue
Submaxillary duct
Lingual nerve
Genio-glossus
Sublingual gland
Genio-hyoid
Periosteum
Tooth abscess
Skin
Digastric, ant. belly
Lymph gland
Abscess
Mylo-hyoid
Hyoid bone
Deep cervical fascia

FIG. 45.—Frontal Section through the Mouth. Four varieties of alveolar abscess are shown. *In the maxilla*, on the right side, the pus has spread laterally, forming an abscess under the mucous membrane; on the left side, it has spread medially, forming a palatal abscess. *In the mandible*, on the right side, the pus has perforated the bone medial to the attachment of the deep cervical fascia, forming an abscess which is covered by the fascia and the skin; on the left side, the pus has perforated the bone outside the deep fascia, forming an abscess immediately under the skin.

(*b*) The *posterior group* lies in relation to the deep and superficial aspects of the submaxillary salivary gland. The superficial glands receive afferents from the lips, gums, and teeth, and from the anterior group. When enlarged they are usually tuberculous, and the infection can be traced to the teeth. The deep glands drain the lateral part of the tongue and floor of the mouth. They may become infected secondarily from chronic tuberculous disease of the superficial glands, but they are primarily and constantly involved in malignant disease of the areas which they drain. The efferents from both groups terminate in the upper anterior group of the deep cervical glands (p. 136).

Good exposure of the region is obtained by a large *curved incision* similar to that already described for ligature of the second part of the lingual artery (p. 149). This incision is useful when a cold abscess points beneath the skin, because the vitality of the skin immediately over the abscess is not interfered with when the flap is turned up. If a sinus is present, the incision may be made straighter so as to excise it entirely. The skin and platysma are undercut to afford good exposure and to permit the edges to be brought together subsequently. As soon as the deep fascia is cut through, the anterior facial vein is exposed, running downwards and backwards on the surface of the submaxillary salivary gland, but it may be displaced or it may be embedded amongst the enlarged lymph glands. It enters the region by piercing the deep fascia at the anterior border of the masseter muscle, just behind the external maxillary (facial) artery, and leaves it, as the common facial vein, by passing superficial to the posterior belly of the digastric. If it is cut, both ends must be ligatured, as they may give rise to severe hæmorrhage, especially when the vessel is injured near its junction with the internal jugular vein (p. 120). After the anterior facial vein has been dealt with, the superficial lymph glands may be removed, but they must be distinguished from the lobules of the salivary gland, which closely resemble them in appearance.

The removal of the deep lymph glands is complicated by their relation to the external maxillary (facial) artery. Normally, the vessel runs first upwards and then forwards and downwards in a well-marked groove on the deep surface of the salivary gland, but it may be displaced or surrounded by the lymph glands when they are enlarged. The salivary gland is turned upwards and the position of the artery is ascertained, but the vessel is liable to be wounded as it crosses the inferior border of the mandible (p. 178). Thereafter the enlarged lymph glands can be safely taken away. If the glands are malignant, the whole group (*i.e.* both superficial and deep), together with the salivary gland and the portion of the external maxillary (facial) artery in relation to it, will require excision, possibly with many neighbouring structures.

Portions of the submaxillary salivary gland may be removed without the occurrence of a salivary fistula, which only follows injury to the duct itself or to its larger tributaries.

The *Genio-hyoid* is a narrow, strap-like muscle, which arises from the lower part of the mental spine (genial tubercle), and is inserted into the hyoid bone. It lies immediately under cover of the mylo-hyoid, and is supplied by the *hypoglossal nerve.* It acts as an elevator of the hyoid bone or as a depressor of the mandible.

The *Genio-glossus muscle* arises just above the genio-hyoid, and it widens out in a fan-shaped manner as its fibres pass backwards. The lowermost fibres run downwards and backwards to the hyoid bone. In front they are covered by the genio-hyoid, and behind they disappear under cover of the hyo-glossus, but between these two muscles they lie in contact with the mylo-hyoid. The uppermost fibres pass into the tongue, under cover of the hyo-glossus. The genio-glossus receives its nerve-supply from the *hypoglossal.* The lower and middle fibres protrude the tongue (Fig. 50), while the upper fibres retract it. When the muscle acts as a whole it depresses the tongue.

The *Stylo-glossus* runs downwards and forwards from the styloid process to the side of the tongue, and in most of its extent it is covered by the mandible. It helps the anterior fibres of the genio-glossus to retract the tongue, and is supplied by the *hypoglossal nerve.*

The **Sublingual Salivary Gland** lies immediately below the mucous membrane of the anterior part of the floor of the mouth, and it forms a small swelling, which can be readily appreciated by the tip of the tongue. It lies on the surface of the anterior part of the genio-glossus, and is placed under cover of the mandible. It possesses *numerous ducts,* which open directly into the floor of the mouth. Occlusion of these ducts gives rise to a cystic swelling (*ranula*), which is sometimes bilateral in the floor of the mouth and lies under the tongue.

The **Lingual Nerve** (p. 187) runs forwards on the upper part of the hyo-glossus above the submaxillary duct, which passes upwards under cover of it anteriorly. It disappears under cover of the sublingual gland, and sinks into the genio-glossus to reach the mucous membrane of the tongue. It supplies the anterior two-thirds of the tongue with ordinary sensation and with the special sense of taste, the latter through the fibres of the chorda tympani, which joins the lingual nerve in the infratemporal fossa (pterygo-maxillary region).

Development of the Neck.—In the early weeks of fœtal life, certain transverse ridges, which are known as the *visceral* or *branchial arches,* appear on each side of the neck, and their inner surfaces project into that part of the foregut (p. 195) which gives rise to the mouth and pharynx. There are six of these arches, but the lower two do not cause any elevation on the ectodermal surface. The arches are separated from one another on the outside by grooves which are termed the *visceral clefts*, and on the inside by grooves which are termed the *visceral pouches*. The grooves, which never break down in the human embryo, consist of an outer layer of ectoderm and an inner layer of entoderm, the two together forming the *cleft membrane*. Each arch contains a bar of cartilage, a muscle mass, a nerve, and an artery.

At the period when the branchial arches develop, the embryo possesses two fused ventral aortæ, which arise from the truncus arteriosus, and two dorsal aortæ. The fused ventral aortæ are connected to each dorsal aorta by *six aortic arches*, each of which supplies one branchial arch and the cleft caudal to it. The cranial ends of the fused ventral aortæ disappear, but a new outgrowth arises near the ventral end of the third aortic arch and grows headwards to form the external carotid artery. The internal carotid artery is derived from the dorsal part of the third aortic arch and the distal part of the dorsal aorta. From this it is clear that branchial fistulæ, which develop in connection with the first or second clefts, must pass deep to the external carotid but superficial to the internal carotid artery.

The *cartilage of the first arch* is known as *Meckel's cartilage*. It is almost entirely replaced by the mandible, but its cephalic extremity forms the malleus and the incus. The *cartilage of the second arch* forms the stapes, the styloid process, the stylo-hyoid ligament, the lesser cornu, and a part of the body of the hyoid bone. The *cartilage of the third arch* forms the greater cornu and the remainder of the body of the hyoid bone, while the *cartilages of the lower arches* take part in the formation of the framework of the larynx.

The *muscle mass of the first arch* develops into the *muscles of mastication*, which are supplied by the nerve of the first arch, the mandibular division of the trigeminal. The *platysma* and the *muscles of facial expression* are derived from the *muscle mass of the second arch*, and are innervated by the facial nerve, which is the nerve of the second arch. The *muscle mass of the third arch* forms the *stylo-pharyngeus*, and its nerve-supply is obtained from the glosso-pharyngeal, which is the nerve of the third arch. It is probable that the constrictor muscles of the pharynx have a similar origin. Lower down in the series our knowledge of the history of the muscle mass is less definite. The *crico-thyreoid* *muscle* is derived from the *fourth arch*, and is supplied by the external branch of the superior laryngeal, which is the nerve of that arch. The *muscle masses of the fifth and sixth arches* form the remaining *intrinsic muscles of the larynx*, which are supplied by the recurrent (laryngeal) nerve—the nerve of these arches. Of the visceral clefts all but the first, which forms the external acoustic meatus, disappear entirely. The first (and possibly part of the second) visceral pouch forms the tympanum and the auditory (Eustachian) tube, so that the tympanic membrane occupies the site of the cleft membrane. Remains of the second pouch form the supra-tonsillar fossa (p. 192).

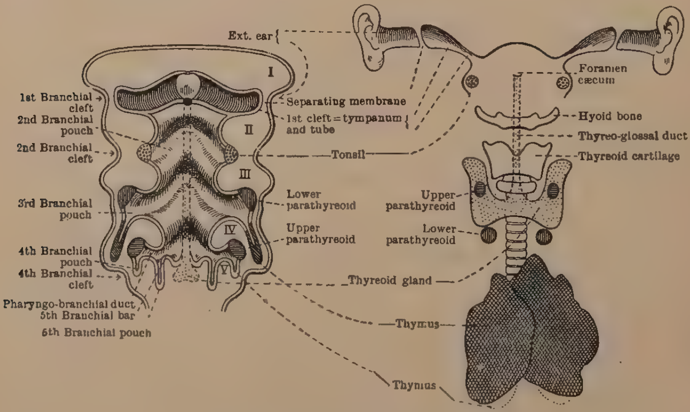

Ext. ear
I
II
III
IV
V
1st Branchial cleft
2nd Branchial pouch
2nd Branchial cleft
3rd Branchial pouch
4th Branchial pouch
4th Branchial cleft
Pharyngo-branchial duct
5th Branchial bar
6th Branchial pouch
Separating membrane
1st cleft = tympanum and tube
Tonsil
Lower parathyreoid
Upper parathyreoid
Upper parathyreoid
Lower parathyreoid
Thyreoid gland
Thymus
Thymus
Foramen cæcum
Hyoid bone
Thyreo-glossal duct
Thyreoid cartilage

FIG. 46.—Scheme showing the Branchial Pouches, Clefts and Arches and some of their derivatives.

The upper two branchial arches develop much more rapidly than the lower arches, which are soon overlapped and hidden by the second. The ectodermal covering of the second arch comes into contact and fuses with the ectoderm caudal to the fourth cleft. In this way the second, third, and fourth clefts no longer open on the surface, but instead they open into a common space termed the *cervical sinus*. This enclosed ectoderm normally disappears, but the persistence of any part of it may lead to the formation of branchial cysts or fistulæ.

A **Blind External Branchial Fistula** is the most frequent deformity arising from persistence of the ectoderm which lines the cervical sinus and normally disappears. It is met with usually near the anterior border of the sterno-mastoid, but the site of the opening in no way locates the individual cleft which is at fault. Just as the upper arches and clefts leave more normal remains than the lower, so it is found clinically that abnormal remains usually belong to the upper members of the series.

In the human embryo the cleft membrane never breaks down as it does in fishes, and it is probable that, in cases where a branchial fistula is stated to have been complete, the thin cleft membrane has been destroyed by the probe or length of fishing-gut or catgut which has been introduced into the fistula to examine its track.

This condition can be satisfactorily treated only by dissecting out the whole track, for, unless this is done, recurrence is certain. An *incision* is made around the fistulous opening, and it is carried upwards along the anterior border of the sterno-mastoid as far as is necessary. A fine probe, introduced into the fistula as it is being dissected, is found to sink gradually through the superficial fascia and the platysma, and to pierce the deep fascia about the level of the upper border of the thyreoid cartilage.

In the majority of cases the fistula is derived from the second visceral cleft. Consequently, as it is traced upwards, it will be found to lie superficial to the structures derived from the third and lower arches, *e.g.* the internal carotid artery and the glosso-pharyngeal nerve, but deep to those developed in relation to the upper two arches. It is therefore crossed by the lingual, occipital, posterior auricular, and external carotid arteries, and by the stylo-hyoid ligament and the hypoglossal nerve. If the fistula extends upwards to the region of the supra-tonsillar fossa or the pharyngeal recess (of Rosenmüller) (p. 194), it will pass between the stylo-hyoid and stylo-pharyngeus muscles, and it has already been explained (p. 153) why the fistula must pass between the two carotid arteries. In order to remove the upper part of the fistula entirely, the probe is pushed through the cleft membrane into the supra-tonsillar fossa or pharyngeal recess, as the case may be. The fistula is then divided, and, after the lower part has been removed, the upper part is attached to the probe and turned inside out by pulling the probe out through the mouth. In this way the whole of the fistula can be completely excised.

Branchial cysts may be mistaken for enlarged lymph glands, but they only occur singly and are unilateral. They contain a glairy fluid under normal conditions, but if they are infected there may be some difficulty in making a correct diagnosis until the cyst wall is exposed. Unlike other simple cysts, they are situated under the deep fascia, and closely resemble a glandular abscess.

The Anterior Median Line of the Neck.—This area may be subdivided into (1) a supra-hyoid or lingual region, (2) a laryngeal region, which extends from the hyoid bone to the cricoid cartilage, and (3) a tracheal region, lying below the cricoid cartilage.

The **Supra-hyoid Region** is triangular in shape. It is bounded laterally by the anterior bellies of the two digastric muscles and below by the hyoid bone. The roof is formed by the investing layer of the deep cervical fascia, which is attached to the mandible above and to the hyoid bone below, and blends with the fascial sheaths of the digastric on each side. The floor of the region is formed by the two mylo-hyoid muscles, which meet at the median raphe (p. 148).

The *submental or supra-hyoid lymph glands* are two small pea-like bodies which lie just above the hyoid bone, and they can often be felt in the living subject. They receive afferents from the chin, the central portions of the lower lip, the lower incisor teeth and gums, the floor of the mouth, and the tip of the tongue. Abscess or lymph-adenitis in connection with the submental lymph glands causes a swelling which projects downwards below the chin, as it is prevented from rising up into the mouth by the mylo-hyoid muscles. Lingual dermoids, on the other hand, or cysts and solid tumours in connection with remains of the thyreo-glossal duct (p. 173), bulge upwards into the floor of the mouth, since they lie on the deep surface of the mylo-hyoid muscles. The efferents from the submental lymph glands pass laterally on the surface of the mylo-hyoids and open into the submaxillary lymph glands.

Good access to the glands is obtained by a *horizontal incision* just above the hyoid bone. It should pass through the deep fascia, which is undercut so as to expose the anterior bellies of the digastric, and these muscles act as a guide to the level of the slightly deeper floor. The glands can then be removed from the floor of the triangle without trouble.

In the removal of a *lingual dermoid* a vertical supra-hyoid incision is carried through the deep fascia to the muscular floor of the submental triangle, and both edges are undercut. The median raphe is split and the mylo-hyoid muscles are retracted from one another. In the normal condition this procedure would expose the genio-hyoids lying side by side at the median plane, but when a dermoid cyst is present it separates the two muscles. At a deeper level the cyst separates the two genio-glossi, and its upper surface may be in contact with the mucous membrane of the anterior part of the floor of the mouth. The cyst wall is separated from these structures by blunt dissection, but it may have to be evacuated prior to removal.

The surgical approach for removal of advanced malignant disease of the back of the tongue, epiglottis, floor of the mouth, and fauces may be obtained through the supra-hyoid region. A *median vertical incision* is made through the lower lip and skin of the chin and neck down to the hyoid bone. Before the mandible is divided, holes are drilled through it on each side of the symphysis, so that the two halves may subsequently be retained in position by wiring. The bone is then divided, and the median raphe of the mylo-hyoids is split. The two halves of the jaw can now be separated widely, and the mucous membrane of the floor of the mouth is cut through with scissors, near its reflection

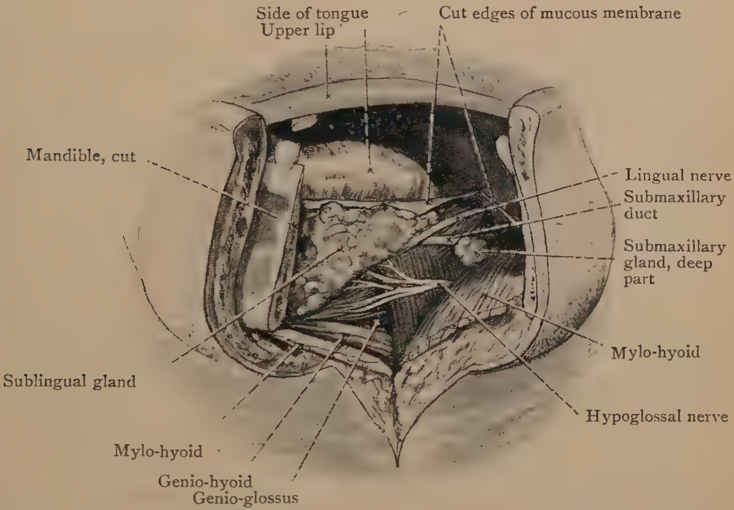

Side of tongue
Upper lip
Cut edges of mucous membrane
Mandible, cut
Lingual nerve
Submaxillary duct
Submaxillary gland, deep part
Mylo-hyoid
Hypoglossal nerve
Sublingual gland
Mylo-hyoid
Genio-hyoid
Genio-glossus

FIG. 47.—Surgical approach for the Removal of Advanced Malignant Disease of the Tongue. The mandible has been divided, lateral to the mental spine, and the mylo-hyoid has been cut. The operation is described below.

on to the gums, from the median plane as far back as the glosso-palatine arch (anterior pillar of the fauces) on the diseased side.

The cutting of the mucous membrane permits the tongue to be dragged over towards the healthy side, and exposes, from before backwards, the sublingual gland lying on the genio-glossus and the submaxillary (Wharton's) duct, and the lingual nerve resting on the upper part of the hyo-glossus (Fig. 47). By blunt dissection the wound is deepened between the hyo-glossus and stylo-glossus medially, and the mylo-hyoid and stylo-hyoid laterally, until the hypoglossal nerve is exposed and the hyoid bone is reached. The hyo-glossus is next cut away from the hyoid bone, and it is probable that the hypoglossal nerve, on the superficial aspect of the muscle, and the lingual artery, on its deep aspect, will be divided at this stage. The submaxillary duct, the lingual nerve, and the stylo-glossus are next cut through. If the palatine tonsil and adjoining mucous membrane are involved, the glosso-palatine arch (anterior pillar of the fauces) is divided and the diseased area taken away. The actual removal of the tongue is described on p. 191.

The **Depressor Muscles of the Hyoid Bone** form a double layer of muscle, clothing the trachea and larynx. The superficial layer consists of the sterno-hyoid and the anterior belly of the omo-hyoid, which lies to its lateral side. The deep layer is formed by the sterno-thyreoid below and by the thyreo-hyoid above. The former is closely applied to the surface of the lateral lobe of the thyreoid gland, while the latter is in relation to the thyreo-hyoid membrane.

The **Ansa Hypoglossi** lies on the anterior surface of the carotid sheath opposite the cricoid cartilage. It is formed by the union of the ramus descendens hypoglossi (p. 127) with a descending branch from the cervical plexus (C. 2 and 3), and it supplies all the depressor muscles of the hyoid bone except the thyreo-hyoid, which is supplied by the hypoglossal nerve (p. 127).

The Laryngeal Region.—The *larynx* is covered by the depressor muscles of the hyoid bone, the lateral lobes of the thyreoid gland, and the crico-thyreoid muscles. It occupies a lower position in the adult than it does in the child. In an infant three months old the cricoid cartilage lies opposite the fourth cervical vertebra.

The *Thyreoid cartilage* consists of two expanded laminæ, which meet in front at an angle, the laryngeal prominence, but are widely separated behind.

From the upper and lower extremities of the posterior border of each lamina the superior and inferior cornua project. The latter articulates with the side of the cricoid cartilage by means of a diarthrodial joint.

The *Cricoid cartilage* is narrow in front, but it is much deeper posteriorly, and helps to fill in the gap caused by the wide separation of the laminæ of the thyreoid cartilage. This gap is still further diminished by the two *Arytenoid cartilages,* which are situated on the upper border of the posterior part of the cricoid. These little cartilages are pyramidal in shape, and their bases articulate with the cricoid by diarthrodial joints. The anterior basal angle (vocal process) projects forwards and gives attachment to the vocal fold (true vocal cord), while the lateral basal angle (muscular process) receives important muscular attachments. At its apex the arytenoid cartilage is capped by the *corniculate cartilage* (*of Santorini*).

The *thyreo-hyoid membrane* connects the upper border of the thyreoid cartilage to the upper and posterior part of the hyoid bone. Its superficial surface is closely applied to the thyreo-hyoid muscle, while its deep surface is separated from the epiglottis and the anterior wall of the laryngeal vestibule by a pad of fat. A bursa is placed between the posterior surface of the hyoid bone and the upper part of the thyreo-hyoid membrane to facilitate the movements of swallowing, in which the thyreoid cartilage ascends behind the hyoid bone. When it is enlarged the bursa may be mistaken for a thyreo-glossal cyst (p. 173), as it lies in the median plane, but the laryngeal lymph glands, which also lie on the thyreo-hyoid membrane, and the possible presence of accessory thyreoids must be borne in mind when making the diagnosis.

The *conus elasticus* (*crico-thyreoid membrane*) is attached below to the upper border of the cricoid cartilage, and passes upwards under cover of the lower border of the lamina of the thyreoid cartilage. Its upper border is attached in front to the deep surface of the thyreoid angle, and, behind, to the vocal process of the arytenoid cartilage. In the rest of its extent it is free and forms the vocal ligament, which is one of the important constituents of the vocal fold (true vocal cord).

The *epiglottis* is a leaf-shaped cartilage, which lies in the anterior wall of the laryngeal vestibule. Its wide upper end is free and projects above the hyoid bone in relation to the dorsum of the tongue, while its narrow lower end is attached to the deep surface of the thyreoid angle. Anteriorly, the epiglottis is separated from the thyreo-hyoid membrane by a pad of fat, and is attached by a ligament to the deep surface of the hyoid bone. The mucous membrane passes from the dorsum of the tongue to the front of the upper part of the epiglottis, forming the floor of a depression, which is divided into two by the *glosso-*

epiglottic fold. These depressions—the *valleculæ*—are bounded behind by transverse ridges, which extend from the side of the epiglottis to the lateral walls of the pharynx. The floor of the vallecula lies immediately above and behind the hyoid bone (Fig. 50).

Over the free upper border of the epiglottis the mucous membrane of the mouth becomes continuous with that of the larynx. A fold of mucous membrane stretches from each side of the epiglottis downwards, backwards, and medially to the apex of the arytenoid cartilage (*ary-epiglottic folds*). These folds, together with the epiglottis, form the boundaries of the upper opening into the larynx, and owing to the obliquity of its lateral margins, the plane of the opening looks almost directly backwards. Between the ary-epiglottic fold and the pharyngo-epiglottic fold the mucous membrane lines a small depression—the *recessus piriformis*—which lies in close relation to the deep surface of the thyreo-hyoid membrane. This area is supplied

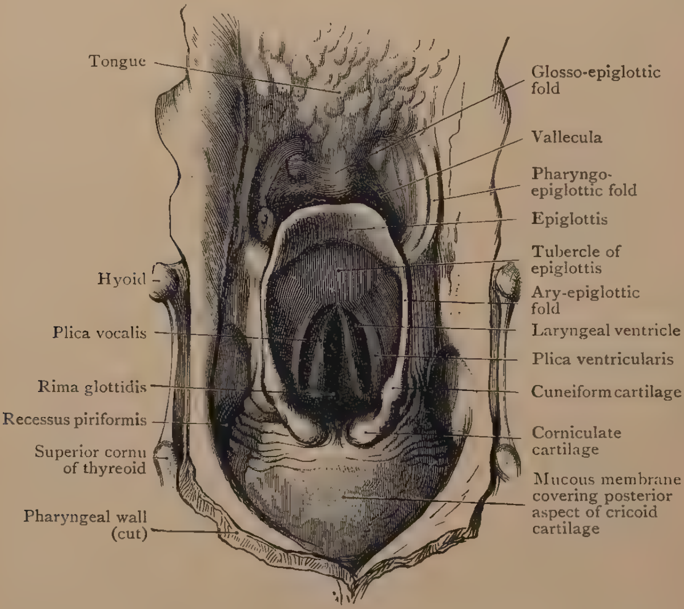

Tongue
Hyoid
Plica vocalis
Rima glottidis
Recessus piriformis
Superior cornu of thyreoid
Pharyngeal wall (cut)
Glosso-epiglottic fold
Vallecula
Pharyngo-epiglottic fold
Epiglottis
Tubercle of epiglottis
Ary-epiglottic fold
Laryngeal ventricle
Plica ventricularis
Cuneiform cartilage
Corniculate cartilage
Mucous membrane covering posterior aspect of cricoid cartilage

FIG. 48.—Upper Aperture of the Larynx, exposed by cutting through the posterior wall of the pharynx.

by the internal laryngeal nerve, and the lodgment of foreign bodies in it at once sets up a fit of uncontrollable coughing. They may be removed by the finger, which is passed backwards into the mouth close to the dorsum of the tongue, until the epiglottis is felt. The recessus piriformis can be explored postero-lateral to the epiglottis (Fig. 48).

The uppermost part of the larynx is termed the *vestibule*. Its cavity narrows from above downwards, and is limited below by two inwardly projecting ridges on its lateral walls, the ventricular folds (false vocal cords).

The *laryngeal ventricle* is bounded above by the ventricular folds, and below by the **vocal folds (true vocal cords)**, which are separated from one another by the rima glottidis, and lie on a level with the fifth cervical vertebra. The vocal fold consists of the ligamentum vocale (p. 159), to the lateral aspect of which the vocalis muscle is closely applied. Its medial aspect is so firmly bound down to the mucous membrane that it presents a whitish colour on laryngoscopic examination. In front, the vocal fold is attached to the thyreoid angle, and behind, to the vocal process of the arytenoid cartilage. The intimate relation of the mucous membrane to the vocal fold is of great importance in connection with *œdema glottidis*. Elsewhere in the larynx the submucous tissue is very lax and distensible. When œdema occurs in this situation it cannot spread downwards beyond the vocal folds. In consequence, the laryngeal ventricle may be so encroached on by the swollen mucous membrane as to hinder the in-take of air to a serious or even fatal extent.

The *rima glottidis* is the narrowest part of the respiratory tract, and measures 1 inch antero-posteriorly by $\frac{1}{3}$ inch transversely. It corresponds in level to the lower part of the laryngeal prominence.

On *laryngoscopic examination* the observer can see the expanded upper end of the epiglottis and the ary-epiglottic folds. In the posterior part of the latter two elevations can be made out; the posterior is produced by the corniculate cartilage (of Santorini), and the anterior by the cuneiform cartilage (of Wrisberg), which is a nodule of yellow elastic cartilage embedded in the fold. Within the boundaries of the aperture both the ventricular and vocal folds (false and true vocal cords) can be examined (Fig. 49). The former, which are reddish in colour, are more widely separated, as a rule, and have only a small range of movement; the latter are whitish in colour and move freely during phonation. In quiet respiration the rima glottidis is triangular with the apex in front, but in forced breathing it becomes diamond-shaped owing to lateral rotation of the vocal processes of the arytenoids. During high notes the vocal folds become adducted, and only the posterior part of the glottis, *i.e.* the part between the two arytenoids, remains open. A yellowish elevation may be observed in the posterior part of the vocal fold. It is due to the vocal process of the arytenoid.

In addition to the boundaries of the aperture and the interior of the larynx, a good view may be obtained of the recessus piriformis and the valleculæ, and if the vocal folds are widely abducted, the interior of the trachea may be examined. It must be remembered that irregular appearances may be caused by the cicatricial contraction which commonly follows ulceration in this region.

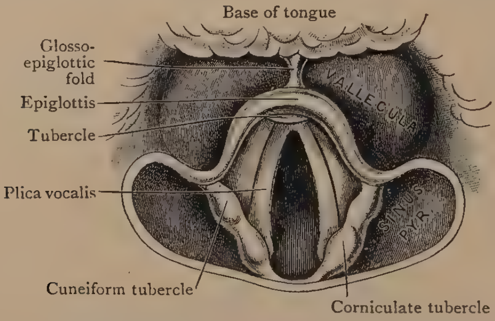


FIG. 49.—The Larynx as seen in the living subject by means of the Laryngoscope.

Polypi and other growths, which may occur in relation to the epiglottis, ary-epiglottic folds, ventricular and vocal folds, may be removed *via* the mouth by the intralaryngeal method. If this is not possible, satisfactory access may be obtained by sub-hyoid pharyngotomy (p. 163) or thyreotomy (p. 166).

The *lymph vessels of the larynx* may be subdivided into a supraglottic and an infraglottic group. They communicate freely with one another in the posterior wall of the larynx, but across the vocal folds the connections are few and irregular. The supraglottic efferents follow the course of the internal laryngeal nerve (p. 163) and open into the upper anterior group of the deep cervical lymph glands. The infraglottic efferents run downwards in the groove between the trachea and the œsophagus, close to the recurrent nerve, and open into the lower anterior group of the deep cervical lymph glands. In extrinsic cancer of the larynx the supraglottic lymphatics are involved, but in the intrinsic variety the spread occurs along the infraglottic vessels.

The upper aperture of the larynx can be brought to the surface by the operation of **Sub-hyoid Pharyngotomy.** A *transverse incision* is made just below the hyoid bone. This divides the skin, the superficial fascia, the platysma, and the deep fascia. The sterno-hyoid, the omo-hyoid, and the thyreo-hyoid are cut through, but their upper ends are left sufficiently long to allow them to be sutured subsequently. The thyreo-hyoid membrane, which is now completely exposed, is incised horizontally, and in doing so the surgeon is careful not to injure the internal laryngeal nerve and its accompanying artery (p. 123) by extending the incision beyond the lateral border of the thyreo-hyoid muscle.

The *internal laryngeal nerve* is a branch of the superior laryngeal nerve, which arises from the vagus a little below the base of the skull. It runs obliquely downwards, forwards, and medially, deep to both carotid arteries, and pierces the thyreo-hyoid membrane at the posterior border of the thyreo-hyoid muscle. It supplies the mucous membrane of the larynx and recessus piriformis. Section of one internal laryngeal nerve renders the mucous membrane of that half of the larynx insensitive, but should both nerves be cut, inhalation pneumonia is likely to supervene owing to the loss of the cough reflex.

After opening the thyreo-hyoid membrane, the surgeon cuts upwards and backwards, through the underlying pad of fat, and divides the ligament which attaches the epiglottis to the hyoid bone. Above the ligament lie the submucous tissue and mucous membrane of the valleculæ, and when these have been incised the epiglottis can be pierced by a strong silk ligature and dragged out through the wound. This proceeding brings the vestibule of the larynx directly to the surface, and affords excellent exposure of the area.

Cut Throat.—The commonest sites of the wound in "cut throat" are immediately above and below the hyoid bone. By throwing back his head while he makes the wound, the suicide unconsciously protects the main vessels from danger, as the action retracts the carotid sheath and its contents more deeply under cover of the sterno-mastoid. The *supra-hyoid incision* cuts through the mylo-hyoids, genio-hyoids, hyo-glossi, and

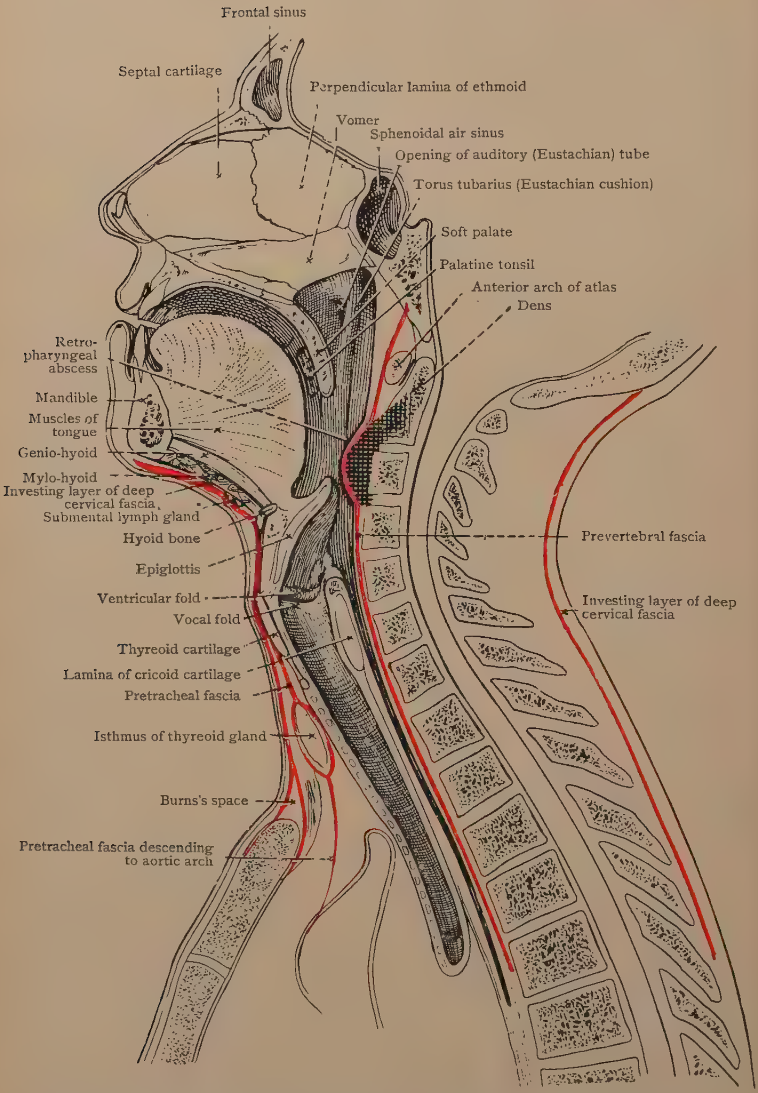

Frontal sinus
Septal cartilage
Perpendicular lamina of ethmoid
Vomer
Sphenoidal air sinus
Opening of auditory (Eustachian) tube
Torus tubarius (Eustachian cushion)
Soft palate
Palatine tonsil
Anterior arch of atlas
Dens
Retro-pharyngeal abscess
Mandible
Muscles of tongue
Genio-hyoid
Mylo-hyoid
Investing layer of deep cervical fascia
Submental lymph gland
Hyoid bone
Epiglottis
Ventricular fold
Vocal fold
Thyreoid cartilage
Lamina of cricoid cartilage
Pretracheal fascia
Isthmus of thyreoid gland
Burns's space
Pretracheal fascia descending to aortic arch
Prevertebral fascia
Investing layer of deep cervical fascia

FIG. 50.—Median Section through Head and Neck. A tuberculous abscess is depicted, originating in the body of the second cervical vertebra and descending behind the prevertebral fascia.

genio-glossi, and if it begins sufficiently far back it emerges through the dorsum of the base of the tongue. The lingual vessels and hypoglossal nerve are divided, but the lingual nerve usually escapes as it lies above the level of the wound. More posteriorly, the external maxillary (facial) artery and common facial vein—which is usually the first large vessel to be severed—are reached, but the carotid sheath is only injured when the incision is a very large one.

The *infra-hyoid wound* closely resembles the incision for sub-hyoid pharyngotomy (p. 163). Laterally, it cuts through the superior thyreoid artery and internal laryngeal nerve before reaching the sterno-mastoid and the carotid sheath. The epiglottis is apt to be divided, and when it is cut its upper part may cause respiratory obstruction.

"Cut throat" wounds through or below the thyreoid cartilage are by no means common.

The *crico-thyreoid muscle* arises from the side of the cricoid cartilage, and passes upwards, backwards, and laterally, to be attached to the thyreoid cartilage. When the crico-thyreoid contracts it elevates the anterior part of the cricoid cartilage, as the thyreoid is held firmly in place by the sterno-thyreoid and thyreo-hyoid muscles. This movement depresses the posterior part of the cricoid together with the arytenoids, and thus separates the posterior from the anterior attachment of the vocal folds, rendering them tense. The *external laryngeal nerve*, which supplies the muscle, is a branch of the superior laryngeal (p. 163), and lies in close relation to the upper pole of the lateral lobe of the thyreoid gland. Should the nerve be stimulated by the pressure of forceps during operations in its neighbourhood, the resulting muscular response may be so strong as to cause spasm of the glottis.

The condition of *laryngismus stridulus* is due to reflex stimulation of the external laryngeal nerve. It may be caused by direct pressure on the main trunk of the vagus itself from tuberculous abscesses or enlarged lymph glands in the thorax. Spasm of the glottis may also occur in gastric disorders, in which case the afferent impulse travels along the vagus itself, and in the disturbance due to dentition, when the afferent impulse is carried up to the sensory nucleus of the trigeminal, from which it spreads to the motor nucleus of the vagus.

As the two crico-thyreoid muscles diverge from each other the crico-thyreoid ligament (middle part of crico-thyreoid membrane) is exposed in the interval between them. Through this area the surgeon performs the operation of **laryngotomy,** which may be carried out as an emergency operation when some foreign body lodges in the larynx, or as a preliminary step in extensive operations on the jaws or mouth. The *incision* is vertical as it passes through the superficial structures, but the actual opening in the ligament is made transversely. In this way injury to the crico-thyreoid artery is avoided, and the cartilages can be separated widely to facilitate the introduction of the laryngotomy tube. Unlike a tracheotomy tube, which is circular on section, a laryngotomy tube is oval so as to fit accurately into the narrow gap between the cricoid and thyreoid cartilages. Laryngotomy is not performed in children owing to the extreme narrowness of the crico-thyreoid ligament.

In the operation of **Thyreotomy,** or splitting of the thyreoid cartilage, great care must be exercised to avoid injuring the vocal folds. The operation is performed through a vertical median incision, which passes between the depressor muscles of the hyoid and the anterior jugular veins of the two sides. A small opening is made in the crico-thyreoid ligament above the crico-thyreoid artery, and the thyreoid cartilage is split with scissors. In advanced age, calcification of the cartilage may render the use of a Gigli saw necessary. It is introduced below, and passed up through the rima glottidis and brought out through a second small opening in the thyreo-hyoid membrane.

Laryngectomy.—In excision of the larynx the best approach is obtained by a *median incision,* which commences at the hyoid bone, and is carried downwards beyond the isthmus of the thyreoid gland. A short transverse incision is made at each end, and two flaps, consisting of skin, superficial fascia, and platysma, are turned laterally. The superficial layer of depressor muscles (p. 156) is divided, and the sterno-thyreoid is cut across low down. This procedure exposes the thyreoid gland below and on each side of the larynx. The pretracheal fascia is incised along the medial border of the upper pole of the gland on each side, and the isthmus is divided between ligatures. In this part of the operation the superior thyreoid arteries (p. 171) must be carefully preserved. The gland can now be separated from the larynx and the trachea, which is exposed lying on the anterior surface of the œsophagus. The trachea is separated from the œsophagus by blunt dissection as high up as the lower border of the inferior constrictor. The recurrent (laryngeal) nerve and the inferior laryngeal artery pass upwards under cover of the muscle, and may be divided at this stage. The trachea is cut through near the cricoid cartilage, and its lower end is turned forwards and stitched to the lower margin of the skin incision, since it tends to retract into the thorax.

The larynx is next retracted upwards and forwards, and the inferior constrictor and the stylo-pharyngeus are divided. In separating the larynx from the lower part of the pharynx, care must be taken not to "button-hole" the mucous membrane on the posterior aspect of the cricoid (p. 193). At the upper border of the cricoid the pharynx is opened, and the epiglottis may be cut across if it is not involved. The larynx is now only fixed above and in front. The thyreo-hyoid muscle and membrane are divided, and the cut is carried backwards through the subjacent pad of fat till the divided epiglottis is reached. After division of the internal laryngeal nerve and its accompanying artery the larynx can be removed. If the epiglottis is involved in the disease, the latter part of the operation follows the course of a sub-hyoid pharyngotomy.

The **Trachea** begins immediately below the cricoid cartilage, and ends opposite the lower border of the fourth thoracic vertebra by dividing into the two bronchi. It is about 4½ inches long, and its diameter varies from ¾ inch to one inch. The cervical part of the trachea is 2¾ inches long, and as it descends it becomes more deeply placed, so that at the upper border of the manubrium sterni it lies 1½ inches from the surface. In children of from three to five years of age the cervical part of the trachea is 1½ inches long and only ¼ inch wide. These measurements give some indication of the variations necessary in the diameters of tracheotomy tubes.

The trachea is freely movable, since it is surrounded by loose cellular tissue, and when necessary it can be retracted to one or other side without much difficulty. The isthmus of the thyreoid gland lies in front of the second, third, and fourth rings of the trachea, while the lateral lobes lie one on each side in relation to the upper six rings and to the cricoid and thyreoid cartilages.

The posterior surface of the trachea, which is in contact with the œsophagus, is flattened so that the tube is horseshoe-shaped on section. This is due to a deficiency in the cartilaginous rings posteriorly. The posterior wall consists of the mucous membrane and the fibro-elastic coat of the trachea. If the surgeon, in performing tracheotomy, opens the trachea too vigorously, he may slit the posterior wall and open into the subjacent œsophagus.

The operation of **High Tracheotomy** is performed through the interval between the cricoid cartilage and the isthmus of the thyreoid gland. It is usually carried out for some form of laryngeal obstruction, and has been labelled an "emergency" operation. There is, however, no necessity for excessive hurry, because, provided that the patient is not further embarrassed by the administration of a totally unnecessary anæsthetic, respiration can always be restarted after the trachea is opened. During the operation the neck is well extended over a small sandbag or cushion, and is held in position in the middle line by an assistant until the tracheotomy tube has been inserted. In this way the trachea is steadied and drawn tight, for its rounded shape renders it liable to be pushed aside, especially if the head is not held absolutely in the middle line, in which event the œsophagus may be opened by mistake. The *incision* may be either vertical or horizontal as it divides the skin and superficial fascia, but it should pass vertically between the two anterior jugular veins. On account of the obstruction to respiration these veins are engorged and may almost touch one another. The investing layer of the deep fascia is incised vertically, and if the subjacent sterno-hyoids are close together they must be retracted. The surgeon now feels for the cricoid cartilage and the isthmus of the thyreoid gland, and when these guides have been identified he makes a transverse cut through the pretracheal fascia just below the cricoid cartilage. The isthmus of the thyreoid gland, with its fascial sheath derived from the pretracheal fascia, can now be retracted downwards, exposing the upper rings of the trachea. A vertical incision is then made in the exposed part of the trachea from below upwards, the back of the knife being directed to the isthmus of the thyreoid gland to avoid injuring the anastomosing terminal branches of the superior thyreoid arteries on its upper border. If sufficient room is not obtained by this method, the cricoid cartilage may be divided, or the isthmus of the thyreoid gland may be cut through. It is said (Treves) that there is no danger of thyreoidism by absorption from the unligated portions of the gland. When the tube is inserted care must be taken not to pass it down the outside of the trachea amongst the depressor muscles nor between the fibro-elastic membrane, in which the cartilaginous rings are embedded, and the mucous lining.

Low Tracheotomy is usually performed to relieve dyspnœa

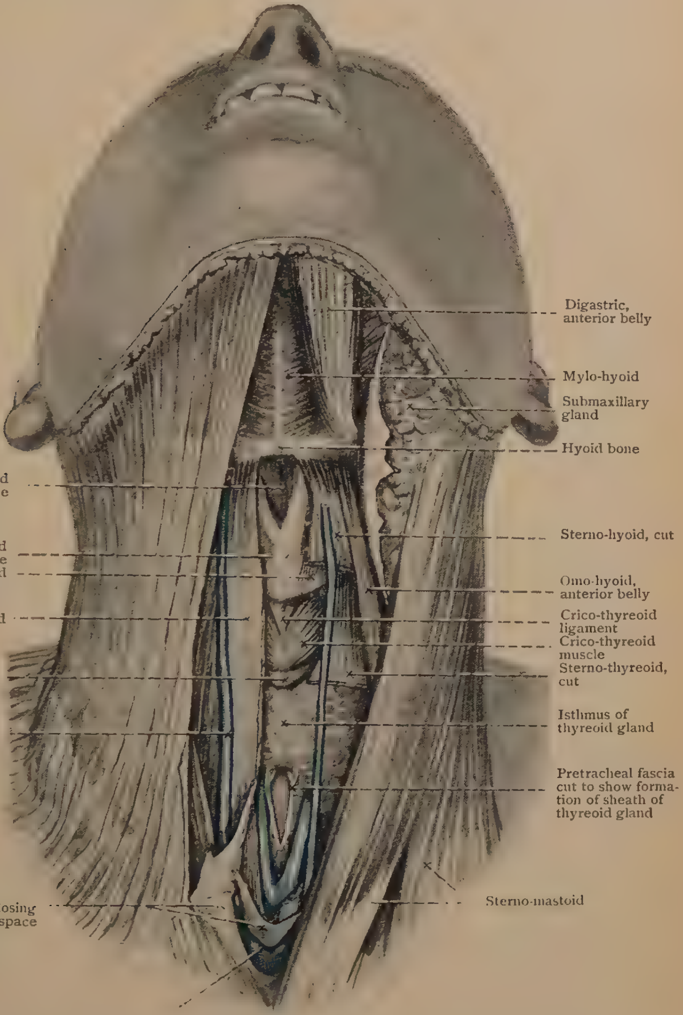

Digastric, anterior belly
Mylo-hyoid
Submaxillary gland
Hyoid bone
Thyreo-hyoid membrane
Thyreoid cartilage
Thyreo-hyoid
Sterno-hyoid
Sterno-hyoid, cut
Omo-hyoid, anterior belly
Crico-thyreoid ligament
Crico-thyreoid muscle
Sterno-thyreoid, cut
Cricoid cartilage
Anterior jugular vein
Isthmus of thyreoid gland
Pretracheal fascia cut to show formation of sheath of thyreoid gland
Fascia enclosing suprasternal space
Sterno-mastoid
Connection between anterior jugular veins

FIG. 51.—The Anterior Median Line of the Neck. *On the left side* the platysma has been removed, and the sterno-hyoid and sterno-thyreoid have been partially resected.

produced by malignant disease of the thyreoid gland. In this operation the trachea is opened below the isthmus of the thyreoid gland, and the wound will necessarily be deep, as this part of the trachea lies at some distance from the surface. On this account the skin *incision* must be a long one, and it should extend down to the jugular (supra-sternal) notch or on to the sternum. It is vertical in direction, and passes through Burns's space (p. 113). In the cellular tissue which occupies the space, the communicating branch between the two anterior jugular veins must be found (Fig. 51), ligatured, and divided. The posterior wall of the space is then cut through and a collection of loose fat is encountered. In this fat, which also contains a few lymph glands, the inferior thyreoid veins descend in front of the trachea from the lower and medial surfaces of the lateral lobes of the thyreoid gland. The veins of the two sides may unite and join the left innominate vein, or they may open separately into the right and left innominate veins. When present, the thyreoidea ima artery ascends in this fat from the innominate artery to the lower border of the isthmus of the thyreoid gland. All these vessels may require to be tied before the pretracheal fascia is divided. The trachea is then incised from below upwards lest any injury be done to the left innominate vein or the innominate artery, which sometimes occupy a higher position than usual.

In children low tracheotomy may be rendered very difficult owing to the shortness of the neck and the presence of the thymus gland. Further, the position of the innominate artery and the left innominate vein is slightly higher than in the adult.

The **Thymus Gland** is of relatively large size in the fœtus ; it continues to grow until puberty, but thereafter it undergoes almost complete atrophy. It consists of a right and a left lobe, closely bound together in a fascial sheath, and lies in the superior mediastinum, in front of the trachea and great vessels, and immediately behind the manubrium sterni. Recent observations tend to show that in the infant certain obscure conditions, which are associated with dyspnœa and stridor, are due to hypertrophy of the thymus gland, and the operation of *subtotal subcapsular thymectomy* has been performed successfully in several cases.

The method of approach is the same as that employed in low tracheotomy. The gland is found behind the posterior wall of Burns's space, and one lobe may be shelled out from its sheath by blunt dissection.

The **Thyreoid Gland** consists of an isthmus and two lateral lobes. The position and relations of the isthmus are referred to on p. 167. Each lateral lobe is conical in shape; the broad base extends downwards as far as the sixth ring of the trachea, and the apex passes upwards on to the lamina of the thyreoid cartilage. The medial surface of the lateral lobe is closely applied to the trachea and larynx, in front, and to the œsophagus and pharynx, behind. Postero-laterally the gland is in contact with the carotid sheath, while its antero-lateral surface lies under cover of the depressor muscles of the hyoid bone (Fig. 36). Sometimes an additional lobe—*the pyramidal lobe*—is present. It ascends from the upper border of the isthmus on one or other side of the median plane, and it may be attached to the hyoid bone by a fibro-muscular slip, termed the levator glandulæ thyreoideæ.

The pretracheal fascia invests the gland with a *fibrous sheath*, which is thickest on its deep and postero-lateral aspects, and is very adherent to the trachea behind the isthmus. The gland can easily be separated from its sheath, save on the posterior aspect of the isthmus where the two are intimately connected. In addition to its loose fascial sheath, the gland is provided with a complete *fibrous capsule*, which envelops it closely, and sends in numerous fibrous septa to separate the lobules and acini from one another. The numerous blood-vessels of the gland run in the fibrous septa, and are brought into close contact with the outer aspects of the acini.

The *blood-supply* of the thyreoid gland is derived from the superior and inferior thyreoid arteries (pp. 123, 147). The former is mainly distributed to the medial surface of the upper pole of the lateral lobe and to the isthmus; the latter supplies the lower pole and lateral surface. It has recently been suggested (Williamson) that the superior thyreoid arteries supply only the interstitial tissue and that the inferior is the true functional artery of the gland. The same author holds that a leash of lymph vessels pass downwards from the thyreoid and enter lymph spaces in the thymus gland.

In the operation of **Thyreoidectomy** it is advantageous to have the patient's head, neck, and thorax on a slight upward incline in order to diminish the hæmorrhage. *Kocher's collar incision* or the *angular incision* may be employed, and both give good access to the gland. The angular incision begins on the posterior border of the sterno-mastoid at the level of the hyoid bone, passes downwards and medially to the cricoid cartilage, and is then carried vertically downwards in the median line to the jugular (supra-sternal) notch. In the upper part of the wound the incision is deepened through the superficial fascia and the platysma, and, after the external jugular vein has been dealt with, the flap is undercut and turned downwards and laterally. The investing layer of the deep cervical fascia is divided vertically between the anterior jugular veins, which are both secured, and the depressor muscles of the hyoid are then identified. Sometimes the muscles are spread out in a thin sheet over the tumour, and the recognition of their edges may offer some difficulty. The sterno-hyoid and the omo-hyoid are divided high up to preserve their nerve-supply, and in such a way that they can be reunited at a later stage. The sterno-thyreoid, which is now exposed, is carefully raised from the surface of the gland so as to avoid injuring the superior and the middle thyreoid veins (p. 121), and it is then cut across. The thyreoid veins are now doubly ligatured and divided lest they should be torn during the subsequent manipulations. The incision is deepened in the median line between the two sterno-thyreoids, and passes through the pretracheal fascia, which forms the loose fascial sheath of the gland. The surgeon can now introduce a finger into the space between the sheath and the true capsule of the gland. This space is crossed by the thyreoid veins and arteries. The surgeon next ligatures the superior thyreoid artery within the sheath, and in this way the external laryngeal nerve, which is associated with the artery outside the sheath, cannot be injured. The upper pole of the gland can now be brought up into the wound, and the isthmus is divided, after it has been separated from the adhesions which bind it to the sheath. The tumour is now more movable, and by turning the lateral lobe forwards and medially, the inferior thyreoid artery may be secured within the sheath and close to the gland. If the sheath is left intact postero-medially, the recurrent (laryngeal) nerve, which crosses the artery in this situation, will not be seen, since it lies outside the fascial sheath (Fig. 36).

The thyreoid gland normally follows the movements of the trachea in swallowing, but when it is the site of malignant disease it becomes adherent to the surrounding structures and fails to do so. This fixation of the thyreoid gland may also be produced by syphilitic adhesions following a broken-down gumma.

Simple tumours of the thyreoid gland rarely give rise to any irritation of the recurrent nerve, but *malignant tumours* frequently do so. Both varieties may cause severe dyspnœa by direct pressure on the trachea. Thyreoid tumours may displace the carotid sheath and its contents laterally into the posterior triangle, or they may enlarge in a downward direction and pass through the thoracic inlet (intra-thoracic variety).

Adenomata or *solitary cysts* of the thyreoid gland may be removed by enucleation. In this operation the capsule and the gland substance are incised until the wall of the cyst or adenoma is reached, and the tumour is then removed by blunt dissection, together with the thinned-out portions of glandular tissue and sheath which lie superficial to it.

Loss of the thyreoid secretion during childhood, either from atrophy or congenital absence of the gland, leads to the condition of *cretinism*, while atrophy or complete removal of the gland in adult life causes *myxœdema*.

The **Parathyreoid Glands** are small pea-like structures, two on each side, which lie normally on the posterior aspect of the lateral lobes of the thyreoid gland, and are most commonly found embedded in its fibrous capsule. The removal of all of these bodies leads to tetany and death. Consequently, in total removal of the thyreoid gland, which is only performed for malignant disease, great care is exercised to leave some of the parathyreoids intact. They can usually be identified by their close relation to an anastomosing vessel which connects the superior and inferior thyreoid arteries on the posterior aspect of the lateral lobe of the gland.

Development of the Thyreoid Gland.—The thyreoid gland arises as a median diverticulum of the entoderm of the floor of the primitive pharynx, and grows tailwards in the interval behind the tuberculum impar (p. 197). In doing so it passes ventral to the cartilages of the second to the sixth visceral arches. At first a hollow bud, the thyreoid rudiment soon becomes solid, and enlarges to form the isthmus and lateral lobes of the gland. Its connection with the floor of the mouth, which is termed the *thyreo-glossal duct*, gradually disappears, and the foramen cæcum on the dorsum of the tongue is all that normally remains of its upper end. The pyramidal lobe and the levator glandulæ thyreoideæ are derived from its lower end.

Occasionally the thyreo-glossal duct is found embedded in the hyoid bone. It is probable that in these cases the thyreoid diverticulum was surrounded by the cartilages of the second and third branchial arches when they fused to form the body of the bone (p. 153). Abnormal remains of the duct may form thyreo-glossal cysts and tumours.

The parathyreoid glands are derived from the entoderm lining the third and fourth visceral pouches (p. 153).

Thyreo-glossal Cysts or tumours may arise in the lingual or cervical part of the duct. In the former case they lie between the genio-glossi (p. 152); in the latter they are median, and lie superficial to the thyreoid or cricoid cartilage. Recurrence of the condition is certain if any procedure short of complete excision is attempted. The operation may be one of great difficulty, as it frequently entails a dissection right up to the foramen cæcum. The procedure is similar to that already described for the removal of a branchial fistula, but it is advisable to resect the central portion of the hyoid bone lest some of the germinal cells of the tract are embedded in it (p. 173). Recurrence of the condition due to neglect of this important detail is now a well-recognised possibility (Stiles).

THE FACE, MOUTH AND PHARYNX

Bony Landmarks.—At the junction of the intermediate and medial thirds of the upper margin of the orbit the *supra-orbital notch* can be examined, and the supra-orbital nerve, which it transmits, can be rolled against the bone. The superciliary arch (ridge) lies just above the upper margin of the orbit and is more prominent medially. In the middle line the two arches are united by an elevation, the *glabella*; it lies a little above the *nasion*, a depression at the root of the nose, which indicates the naso-frontal suture. If the nasal bones are traced downwards in the median line, their union with the nasal cartilages will be recognised by a slight depression, and on each side of the nose at this level the margins of the apertura piriformis (osseous anterior nares) can be felt. The *anterior nasal spine* is recognised by placing the finger on the middle of the upper lip and pressing upwards against the nasal septum.

The zygomatic process of the temporal bone runs forwards from the tragus to articulate with the zygomatic (malar) bone, forming the *zygomatic arch*. Below the anterior part of the arch the fingers can be inserted into the infra-temporal (zygomatic) fossa, but the temporal fascia, which is attached to the upper border of the arch, is so dense that the temporal fossa cannot be explored in the same way. The tubercle of the zygomatic (malar) bone is felt when the upper border of the arch is traced forwards and upwards, and half an inch above it the zygomatic process (external angular process) of the frontal bone is encountered. The *pre-auricular point* is situated on the zygomatic process of the temporal bone immediately in front of the tragus. Here the superficial temporal vessels can be compressed against the bone as they cross the zygomatic arch.

Immediately in front of the tragus and below the root of the zygomatic process of the temporal bone the *condyle of the mandible* can be made out, and when the mouth is opened it slides forwards so that the finger can be inserted into the hollow of the mandibular fossa. If the finger is placed immediately below the zygomatic bone the *coronoid process* impinges on it when the mouth is opened, and it can be traced downwards into the anterior border of the ramus of the mandible. The coronoid process can also be examined from the inside of the mouth, and the tense band of the pterygo-mandibular raphe (p. 180) is felt on its medial side. The posterior border of the ramus, though masked above by the parotid gland, can be felt through the skin, but its outer surface is completely covered by the masseter. The *angle and outer surface of the body of the mandible* are palpable through their coverings, and with one finger outside and another inside the mouth it is possible to estimate the thickness of the bone and to recognise any thickening or irregularity. Near the lower border of the symphysis, and on its inner aspect, the *mental spine* (genial tubercles) may be felt by pressing upwards through the apex of the submental triangle.

A line drawn from the supra-orbital notch to the lower border of the mandible so as to pass between the two lower premolars will cross the *infra-orbital foramen* a quarter of an inch below the lower margin of the orbit. It also passes through the *mental foramen*, which usually (depending on the age of the subject) lies midway between the upper and lower borders of the mandible.

The **Skin of the Face** possesses numerous sebaceous and sweat glands, and lies in intimate relationship with the subjacent loose connective tissue, in which the muscles of facial expression are embedded. The *absence of deep fascia* from the face allows muscles arising from bone to be inserted directly into the skin, which is therefore freely movable. Further, the laxity of the cellular connective tissue, which is unsupported by deep fascia, facilitates the rapid spread of œdema over large areas. Over the nose, however, the skin is firmly bound down to the subjacent cartilage, and inflammation in this region is acutely painful.

Excellent results are obtained from plastic operations on the face, as the skin can easily be stretched while still in contact with the underlying connective tissue. This latter is well supplied with blood-vessels, and hence the vitality of the skin is not affected.

Cutaneous Nerves.—The whole of the skin of the face, with the exception of an area over the angle of the mandible, is supplied by the three divisions of the trigeminal nerve. The ophthalmic nerve supplies most of the area derived from the fronto-nasal process (p. 195), the (superior) maxillary nerve supplies the area derived from the maxillary process, and the mandibular (inferior maxillary) that from the mandibular arch.

The *supra-trochlear* and *supra-orbital nerves* arise from the frontal branch of the ophthalmic and leave the orbit at its upper margin. The former is the more medial, and supplies a small area of the skin of the forehead. The latter emerges through the supra-orbital notch, accompanied by the supra-orbital branch of the ophthalmic artery, and supplies the skin of the forehead and the front of the scalp. This nerve may require to be divided in cases of severe neuralgia. An incision is made through the eyebrow immediately over the notch and is carried down to the pericranium. In this way the nerve is at once divided; the proximal portion is then found by separating the lower edge of the wound from the pericranium, and a piece of it is resected as it enters the flap, lest spontaneous regeneration should occur.

The terminal branches of the *lacrimal* division of the ophthalmic nerve supply the skin and subjacent conjunctiva of the lateral part of the upper eyelid.

The terminal branches of the *naso-ciliary* (*nasal*) division of the ophthalmic nerve appear on the face as the infra-trochlear and external nasal nerves (Fig. 52).

Branches of the *infra-orbital nerve*, which is the terminal portion of the maxillary, supply the lower eyelid, the side of the nose and the cheek adjoining it, and the upper lip. Severe neuralgia, radiating over the areas indicated, is not uncommon, and the infra-orbital nerve may be exposed by a *horizontal incision* just below the infra-orbital margin and above the foramen of the same name. The incision is carried down to the periosteum, and its lower border is separated downwards by blunt dissection. In this way the nerve is found as it leaves the canal. If the neuralgia affects the teeth and gums of the maxilla, the proximal portion of the nerve, after division, must be twisted out. When this is done the anterior and middle superior alveolar (dental) branches are destroyed, since they arise from the infra-orbital nerve as it lies in its canal in the floor of the orbit.

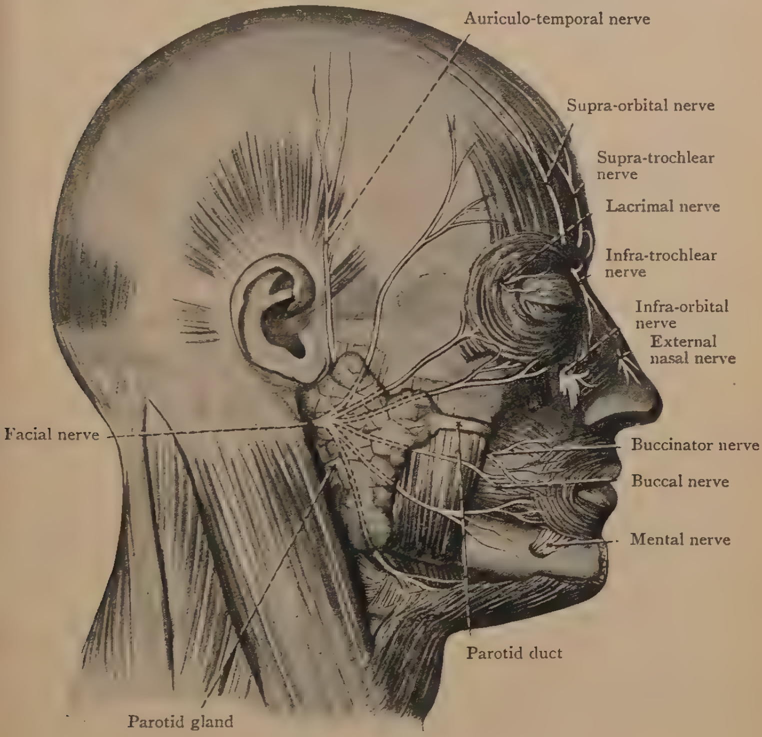

Auriculo-temporal nerve
Supra-orbital nerve
Supra-trochlear nerve
Lacrimal nerve
Infra-trochlear nerve
Infra-orbital nerve
External nasal nerve
Facial nerve
Buccinator nerve
Buccal nerve
Mental nerve
Parotid duct
Parotid gland

FIG. 52.—The Nerves of the Face.

The *zygomatico-temporal* (*temporal*) and *zygomatico-facial* (*malar*) are the only other branches of the maxillary nerve which appear on the face.

Three branches of the mandibular (inferior maxillary) division of the trigeminal supply cutaneous areas in the face.

(1) The *buccinator* (*long buccal*) *nerve* supplies the posterior part of the cheek, and (2) the *mental nerve*, which is the terminal branch of the inferior alveolar, supplies the skin overlying the body of the mandible. In severe neuralgia the mental nerve can be exposed by an *incision* through the outer side of the gum just beneath the lower premolars. The lower part of the wound is retracted downwards, and the nerve is found as it leaves the mental foramen. When the pain also affects the gums and teeth the nerve is twisted out in order to destroy, if possible, the inferior dental plexus within the canal.

(3) The *auriculo-temporal nerve* supplies the skin in front of the ear, and extends upwards to the vertex. In addition, it supplies the skin of the upper part of the auricle and the integument which lines the external acoustic meatus and covers the membrana tympani. On this account foreign bodies in the meatus and chronic inflammatory conditions of its walls commonly cause referred pain over the side of the head.

The remainder of the auricle and the skin over the angle of the mandible are supplied by the *great auricular nerve* (C. 2 and 3).

Congenital cutaneous nævi on the face (" port wine stains ") map out very accurately the areas supplied by one or more divisions of the trigeminal.

The **External Maxillary (Facial) Artery** (p. 124) crosses the inferior border of the mandible just in front of the masseter (1¼ inches from the angle of the mandible), and its pulse can readily be felt in that situation. It then runs upwards and forwards over the bone and the buccinator to a point half an inch lateral to the angle of the mouth, and from there to a point a little behind the ala nasi. Thereafter it ascends to the medial palpebral commissure (inner canthus), where it anastomoses with the terminal branches of the ophthalmic artery. In this situation, therefore, there is an anastomosis between the internal and external carotid arteries. In the lower part of its course the artery is covered by the platysma and the risorius, which blend with one another in the lower part of the face. Near the angle of the mouth it becomes quite superficial, but at a higher level it is crossed by the zygomaticus and by the muscle which elevates the upper lip. The course of the vessel is very tortuous, so that it is not affected by the free movements of facial expression.

A free anastomosis occurs between the vessels of the two sides, and in addition each anastomoses with the transverse facial and middle temporal branches of the superficial temporal artery.

The *superior* and *inferior labial* (*coronary*) *branches* supply the lips and lie in the submucous tissue. During operations on the lips, these vessels are controlled by an assistant, who grasps the lip between his finger and thumb. It should be remembered that they lie very close to the muco-cutaneous junction.

The **Anterior Facial Vein** descends from the medial palpebral commissure (inner canthus), posterior to the external maxillary artery, but its course is much straighter than that of the artery. At its commencement, where it is known as the angular vein (p. 224), it communicates with the ophthalmic veins—and therefore indirectly with the cavernous sinus—and it terminates by uniting with the posterior facial (p. 180) to form the common facial vein, which joins the internal jugular. If it is involved in an acute infective process, such as carbuncle, *septic thrombosis with embolism* may occur owing to the absence of valves. The condition may spread in either direction, for if there is any obstruction to the downward flow, the direction of the stream is at once reversed. If it spreads upwards it may cause thrombosis of the cerebral sinuses, but if downwards it may set free septic emboli into the internal jugular vein. Below the zygomatic bone and in front of the masseter the anterior facial vein communicates freely with the pterygoid venous plexus, and this, in its turn, communicates with the cavernous sinus through the foramen ovale and the foramen Vesalii. Infection may reach the cerebral sinuses by this route, either from the anterior facial vein or from the pterygoid plexus.

The **Parotid Gland** occupies the interval between the mastoid process and the posterior border of the ramus of the mandible, and its deep part rests on the styloid process. It is limited above by the zygomatic arch and the external acoustic meatus, and below it overlaps the posterior belly of the digastric. In front it extends on to the surface of the masseter (Fig. 52). It is completely enclosed by a fascial sheath derived from the deep cervical fascia, which sends fibrous septa into the gland. The superficial portion of the sheath is extremely dense and strong, and offers great resistance to any swelling of the parotid or to any enlargement of the lymph glands which lie embedded within it.

Branches of the great auricular nerve ramify over the surface of the sheath, and the auriculo-temporal nerve pierces it just below the zygomatic process of the temporal bone. Any acute or rapidly growing swelling within the sheath will press on these nerves and give rise to pain, which is referred to the areas of their distribution. In acute parotitis examples of this pain are afforded during the activity of the gland at meal-times.

The facial nerve, the external carotid artery, and the posterior facial (temporo-maxillary) vein are all more or less embedded in the substance of the gland. The nerve traverses the gland and crosses the vessels superficially.

The **Parotid Duct** lies one finger's breadth below the zygomatic arch, and, when the teeth are clenched, it may be rolled up and down against the tense masseter. It emerges from the forepart of the gland, and runs forwards on the masseter to its anterior border. It then passes medially, piercing the buccinator to reach the mucous membrane of the cheek. Opposite the second upper molar tooth the parotid duct opens into the mouth. Septic infection may travel backwards from the mouth along the duct and involve the gland itself.

Calculi lodged in the distal portion of the duct may be removed by slitting up the duct from its opening within the mouth. A similar route is adopted for opening abscesses in connection with the buccinator lymph glands. The *incision* is made horizontally through the mucous membrane to one side of the opening of the parotid duct, and both the mucous membrane and the buccinator are cut parallel to the course of the duct.

The **Buccinator** arises from the outer alveolar margins of the maxilla and mandible in the region of the molar teeth, and its posterior border is attached to the pterygo-mandibular raphe, which is a fibrous band extending from the hamulus of the medial pterygoid lamina (plate) to the posterior end of the mylo-hyoid line of the mandible. Its fibres run horizontally forwards, and fuse with the orbicularis oris at the angle of the mouth. Like the muscles of facial expression, it is supplied by the *facial nerve*. It forms the muscular stratum of the cheek, and when it is paralysed portions of food become retained between the cheek and the gums on the affected side.

The **lymph glands of the parotid region** are divisible into two groups; one, the *anterior auricular* (*pre-auricular*), lies superficial to the sheath, while the other, the group of *parotid lymph* *glands*, is scattered throughout the substance of the gland, though chiefly situated near its surface. The anterior auricular lymph glands drain the frontal and temporal regions and receive some of the deep facial lymph vessels. The parotid lymph glands drain the upper and posterior part of the naso-pharynx and the pterygoid lymph glands. Abscesses arising in connection with the anterior auricular lymph glands point superficially, but, when they arise in connection with the parotid lymph glands, they rarely point on the surface, owing to the strength of the parotid sheath. In these cases the pus may pass upwards and find its way into the external acoustic meatus, or it may travel medially and reach the side wall of the nasal pharynx. In the latter case it ultimately descends along the medial side of the carotid sheath.

Pus inside the parotid gland is evacuated by Hilton's method, but the surgeon must be certain of its presence before exploring the gland. Irreparable damage may be done to the facial nerve by repeated unsuccessful endeavours to locate pus.

An isolated lymph gland of the parotid group, which lies near the surface of the salivary gland at about the level of the tragus, is not uncommonly affected alone. It can be shelled out through a small horizontal incision, parallel to the facial nerve. The superficial structures, the sheath of the gland, and probably some parotid tissue are cut through before it is reached. Mixed tumours of the parotid (as well as some inflammatory swellings) sometimes produce slight facial paralysis. Encapsuled tumours can often be enucleated through a larger incision in the same region without much damage to the facial nerve, provided that all cutting is done parallel to its branches (p. 182).

When **Removal of the whole Parotid Gland** for malignant disease is contemplated, a large *curved incision* is necessary. It commences at the mastoid process, and passes down the anterior border of the sterno-mastoid to a point below the angle of the mandible, and it is then carried upwards and forwards on to the face. The flap is turned upwards, and the external jugular vein and the external carotid artery are secured at once. The gland is most easily freed from below and then from in front, after ligature of the parotid duct. In separating the deep surface of the gland from the muscles attached to the styloid process, care must be taken lest the internal jugular vein be injured, as it may be in direct contact with the gland.

The **Facial Nerve** (pp. 217, 219) leaves the skull at the stylo-mastoid foramen and turns forwards, laterally and slightly downwards. It at once enters the deep surface of the parotid gland and gradually becomes more superficial. At the level of the lobule of the ear, one finger's breadth below the zygomatic arch, the facial nerve may be rolled against the neck of the mandible, although it is here embedded in the parotid gland.

Temporary facial paralysis may result from bruising of the nerve by the application of forceps at birth, as the stylo-mastoid foramen in the infant is placed on the infero-lateral aspect of the skull and the mastoid process is not yet developed (p. 214).

Immediately after it leaves the skull the facial nerve gives off its posterior auricular and digastric branches; the latter supplies the stylo-hyoid in addition to the posterior belly of the digastric. Within the parotid gland the nerve at once breaks up into its main branches, which radiate away from one another as they leave the gland (Fig. 52). They all terminate by supplying muscles of facial expression.

Incisions ascending from the neck behind the angle of the mandible must be only skin-deep at the level of the lobule, otherwise the main trunk of the facial nerve may be divided. Similarly, incisions on the face should be made parallel to its branches of distribution; they should therefore radiate from the middle of the anterior border of the lobule. In the child, up to the age of two, the nerve may be divided by incisions beneath the auricle, such as that employed in mastoiditis (p. 219).

Division of the cervical branch of the facial nerve is referred to on p. 110.

Facio-Hypoglossal Anastomosis is performed for facial paralysis produced by disease or injury of the nerve in its course through the facial canal (aqueduct of Fallopius).

The *incision*, which begins high up on the mastoid process and runs downwards to the greater cornu of the hyoid bone, is planned so as to give good exposure of both nerves.

The deep fascia is incised immediately in front of the mastoid process and the parotid gland is pushed forwards. An aneurism needle is inserted deeply in the gap thus made, and hooked up towards the surface. The facial nerve, which is caught by the needle on a level with the middle point of the lobule of the ear, is traced to the stylo-mastoid foramen and there divided. In order to get a sufficiently long segment of the nerve the bone may require to be chipped away, and the nerve may be traced for a short distance into the parotid gland.

The hypoglossal nerve is found in the anterior end of the wound as it lies in the angular interval between the two bellies of the digastric (p. 149). The incision is carried down through the deep fascia till the posterior belly of the digastric and the submaxillary gland are exposed. This part of the hypoglossal nerve is chosen by the surgeon because a long segment is required to minimise any strain on the subsequent anastomosis. Further, the nerve is easily found in this part of its course, whereas, at a higher level, it lies more deeply, and its isolation would involve considerable risk of injury to the internal jugular vein. The nerve is cut through and withdrawn from under cover of the posterior belly of the digastric. This necessitates section of the branch of supply to the thyreo-hyoid and, perhaps, of the ramus descendens hypoglossi. The proximal extremity of the hypoglossal nerve is then turned up over the posterior belly of the digastric and united to the distal portion of the facial nerve, which is turned down to meet it.

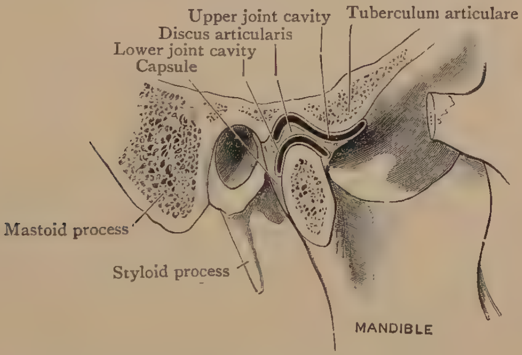


FIG. 53.—Section through the Mandibular Joint.

In similar cases the (spinal) accessory nerve may be united to the facial. It is found at the anterior border of the sternomastoid (p. 139).

Temporo-Mandibular Joint.—At this joint the condyle of the mandible articulates with the mandibular (glenoid) fossa of the temporal bone, which is limited posteriorly by the tympanic plate and in front by the articular tubercle (eminentia articularis). The capsule, which is loose and so permits of free movement, is attached to the margins of the cartilage-covered areas. It gives attachment on its inner surface to the *discus articularis*, which divides the joint cavity into an upper and a lower part. Anteriorly, the capsule is deficient, and the tendon of the external pterygoid gains insertion into the articular disc.

Laterally, the capsule is strengthened by the *temporo-mandibular* (*external lateral*) *ligament*, the fibres of which are directed downwards and backwards to the lower part of the neck of the condyle. The obliquity of these fibres helps to prevent the condyle from passing backwards and fracturing the tympanic plate, when a blow falls upon the chin.

In the movements of protrusion and retraction of the mandible, the condyle and the articular disc move together over the surface of the mandibular fossa. When the mouth is opened the articular disc and the condyle both move forwards, but, at the same time, the condyle rotates forwards and descends slightly, owing to the action of the external pterygoid muscle. The temporo-mandibular (external lateral) ligament becomes tense when the mouth is widely opened and the condyle rests on the summit of the articular tubercle (eminentia articularis). In this position the mandible can easily be dislocated either by a blow on the chin or even by the forcible contraction of the external pterygoids. The method adopted to reduce this dislocation first depresses the condyle so as to disengage it from the front of the articular tubercle, and then, by partial closure of the mouth, the condyle is made to pass back into the mandibular fossa. Considerable force is sometimes required to overcome the spasm of the muscles of mastication.

The *spheno-mandibular* (*internal lateral*) *ligament* is placed at some distance from the joint and gives it no support. Attached above to the spine of the sphenoid, the ligament descends to gain attachment to the margin of the mandibular foramen. The internal maxillary artery and the inferior alveolar (dental) vessels and nerve intervene between the ligament and the ramus of the mandible.

At the symphysis the mandible is strengthened by the *mental protuberance*, and, when fractured, it usually gives way at the margin of this elevation. The fracture passes through the large canine socket and is usually compound, as the mucous membrane of the mouth is so firmly attached to the bone that it is almost always torn. The inferior alveolar (dental) nerve may be implicated in the callus and cause neuralgic pain, which may be referred over the distribution of the buccinator and auriculo-temporal nerves. If the nerve is completely paralysed, the area supplied by its mental branch loses its sensibility, and when drinking, the patient can only appreciate the glass with his lips on the uninjured side.

The *Temporal Muscle* arises from the temporal fossa and descends under cover of the zygomatic arch, to be inserted into the margins and deep surface of the coronoid process. The *Masseter* arises from the zygomatic arch, and is inserted into the lateral surface of the mandibular ramus. Both muscles are powerful elevators of the mandible, and are supplied by the *mandibular division of the trigeminal nerve.*

The *External Pterygoid* arises from the skull in the region of the pterygoid process (plates) of the sphenoid, and passes almost horizontally backwards, to be inserted into the condyle and the articular disc (p. 184). Its action is to draw the condyle and the articular disc forwards, thus protruding the mandible. As it passes backwards it is in contact with the deep surface of the temporal muscle. *The Internal Pterygoid* has a similar but deeper origin. Its fibres run downwards and laterally, as well as backwards, to reach the internal surface of the angle of the mandible. Both pterygoid muscles are supplied by the *mandibular division of the trigeminal.* When the two pterygoid muscles of one side act alone, the mandible is twisted over to the opposite side. This action is seen in lateral chewing movements, and in paralysis of the mandibular nerve the mandible is permanently pulled over to the same side as the lesion.

The **Internal Maxillary Artery** arises from the external carotid in the parotid gland at the level of the neck of the mandible. It passes forwards deep to the bone but superficial to the spheno-mandibular ligament. It may run either superficial or deep to the external pterygoid, and it terminates in the pterygo-palatine (spheno-maxillary) fossa, where it gives off the palatine, infra-orbital, and numerous other small branches. In the earlier part of its course the artery gives off (1) *the middle meningeal,* which ascends deep to the external pterygoid, to enter the skull through the foramen spinosum ; (2) the *inferior alveolar* (*dental*), which enters the mandibular foramen ; and (3) branches to the surrounding muscles. The corresponding veins form a plexus round the pterygoid muscles, which communicates with the cavernous sinus (p. 229) above, the anterior facial vein in front, and the posterior facial vein (temporo-maxillary) behind.

Operations on the Mandible.—The periosteum of the mandible is thick and strong, and can be easily stripped off the bone. Further, it is able to re-form large portions of the bone after subperiosteal resection, an operation which is employed with advantage in tuberculous and chronic septic disease of the body and ramus. A *curved incision* is made along the posterior third of the inferior border of the body, round the angle, and up the posterior border of the ramus. The incision, which must not be carried upwards too far lest the facial nerve be injured (p. 182), penetrates down to the bone, and the periosteum may be stripped off along with the masseter laterally and the internal pterygoid medially, so as to leave the tuberculous bone exposed. The affected area may then be removed without opening into the mouth.

In **Excision of the Mandible** for malignant disease the bone is removed along with its periosteal covering. The *incision* begins at the margin of the lower lip and is carried down in the middle line to the lower border of the bone, along which it is carried backwards to the angle. In this part of the incision, the external maxillary artery and its accompanying vein are cut through and secured. The incision is then carried upwards along the posterior border of the ramus to the level of the tragus. It is only skin-deep above, so that the facial nerve is not injured. The soft parts are reflected from the lateral aspect of the bone and the masseter is cut away from its insertion, and the mucous membrane is divided as it is reflected from the cheek on to the external aspect of the gum. A Gigli saw is passed upwards, internal to the bone, through an opening made in the mylo-hyoid a little to one side of the median plane, and it is brought out into the mouth through the mucous membrane of its floor. The mandible is then divided through the socket of the lateral incisor tooth, and in this way the mental spine (genial elevation), with its muscular attachments, is left intact. The bone is next depressed and dragged outwards through the wound, and the origin of the mylo-hyoid and the mucous membrane on the inner aspect of the gum are cut through, until the internal pterygoid is reached. When the muscle and the spheno-mandibular (internal lateral) ligament, which lies on its surface, have been divided, the inferior alveolar artery and nerve are exposed between them and the ramus. After they have been secured, the bone may be depressed still further so as to bring the coronoid process into view. It may be cut across, or the temporal muscle may be detached from its insertion. The mandible is now only held in position by the external pterygoid and the temporo-mandibular joint.

If these structures are cut through with the knife, the internal maxillary artery (p. 185) is in great danger, and it is safer to twist the condyle away from its attachments.

The **Mandibular (Inferior Maxillary) Nerve** is a branch of the trigeminal, and leaves the skull through the foramen ovale. It at once breaks up into numerous branches, which at first lie deep to the external pterygoid and on the lateral wall of the nasal pharynx.

The nerve may be reached, for the purposes of *injection*, by inserting a needle immediately below the zygomatic arch at a point 2·5 cm. in front of the external acoustic meatus. It is directed medially and slightly backwards to a depth of 4 cm., when the point comes into contact with the nerve (Symington) causing acute pain. Before reaching the nerve, the needle pierces the masseter muscle and passes through the mandibular (sigmoid) notch, the temporal and external pterygoid muscles. If the needle is passed in for more than 4 cm. it pierces the lateral wall of the nasal pharynx.

Branches.—(1) The *Auriculo-temporal nerve* passes backwards into the parotid gland (pp. 178, 215). (2) The *Buccinator* (*long buccal*) pierces the external pterygoid, and frequently the anterior fibres of the temporal, before it appears in the face (p. 178). (3) The *Inferior Alveolar* (*Dental*) *nerve* runs downwards, deep to the external but superficial to the internal pterygoid, and enters the mandibular foramen in company with the artery of the same name. As it enters the foramen it gives off (4) the *Mylo-hyoid nerve* (p. 148). (5) The *Lingual nerve* lies just anterior to the inferior alveolar. On the inner surface of the body of the mandible it lies above the mylo-hyoid line and, opposite the third molar (p. 188) tooth it is only covered by the mucous membrane of the mouth. (6) The *remaining branches* of the mandibular nerve are all motor and supply the muscles of mastication, viz. the temporal, the masseter, and the external and internal pterygoids. Paralysis of this nerve is referred to on p. 239.

The inferior alveolar and lingual nerves are sometimes involved in severe *neuralgia*, which affects the lower teeth and gums and the tongue. They may be approached (1) through the skin of the cheek, or (2) from the inside of the mouth.

1. A curved incision is carried down the lower part of the posterior border of the ramus and forwards along the inferior border of the mandible. This incision passes down to the bone at once, and a flap, consisting of all the superficial structures, including the periosteum, is thrown forwards. The ramus is then trephined slightly above the last molar tooth, and the piece of bone is removed, exposing the periosteum on its deep

surface. This is cut away, and the two nerves are found lying on the internal pterygoid muscle.

2. The mucous membrane of the mouth may be divided upwards and backwards from the level of the last molar tooth of the mandible along the inner surface of the ramus. The lingual nerve is found lying in the submucous tissue, and may be traced backwards between the ramus and the internal pterygoid muscle until the lingula of the mandibular foramen can be felt. The inferior alveolar nerve and vessels are found as they enter the mandibular foramen a little posterior to the lingual nerve.

This operation is carried out when the patient is anxious to avoid a skin incision and the subsequent scar.

Dentition.—The first of the *deciduous teeth* to appear are the lower central incisors, and they are usually cut between the sixth and eighth months. The lateral incisors soon follow, and by the end of the year the first deciduous molars should be visible. Early in the second year the canine teeth erupt, and the temporary set is completed by the appearance of the second deciduous molar about the commencement of the third year. The lower teeth usually appear somewhat in advance of the upper.

The first lower molars are the first of the *permanent teeth* to erupt, and should be present by the end of the seventh year. They are followed during the next two years by the central and lateral incisors. Within the next four years the first and second premolars, the canines, and the second molars appear in that order, but the eruption of the last-named is often delayed till the fifteenth or sixteenth year. The permanent set is completed by the eruption of the third molars, which may appear at any time between eighteen and thirty.

Irregular dentition is common in rickets, and the upper permanent incisors are sometimes notched. The notching corresponds to a small segment of a large circle, and has to be distinguished from the notching of the same teeth in congenital syphilis (*Hutchinson's Teeth*), which corresponds to a large segment of a small circle.

The developing tooth is enclosed in a membranous sac, which, under normal conditions, atrophies as the tooth increases in size. Occasionally, however, the sac fails to atrophy, and develops into a *dentigerous cyst*, which expands the bone. The cyst usually projects more to the lateral than to the medial side, and contains the undeveloped tooth attached to its wall.

Alveolar Abscess.—The roots of the teeth are firmly fixed in their sockets by a highly vascular fibrous membrane, the *alveolo-dental periosteum*. In peri-odontitis this membrane swells up and becomes very sensitive. It tends to extrude the tooth slightly from its socket, so that biting is rendered a painful process. When an alveolar abscess forms, the pus may make its way out around the neck of the tooth or burrow through the alveolus, giving rise to a "gumboil." In the maxilla it may penetrate the bone laterally and appear near the reflection of the mucous membrane from the gum to the cheek, or it may pass medially, stripping up the muco-periosteum, and form an abscess on the palate (Fig. 54). Alveolar abscess in connection with the teeth of the mandible has been described on p. 149.

The **Tongue** is subdivided into a pharyngeal and an oral portion by the *sulcus terminalis*, a V-shaped groove situated at the junction of its middle and posterior thirds. The apex of the V lies posteriorly and coincides with the foramen cæcum (p. 173). Numerous collections of lymphoid tissue are present in the pharyngeal portion of the tongue (*lingual tonsils*). They form small rounded elevations, and each possesses a crypt into which mucous glands open.

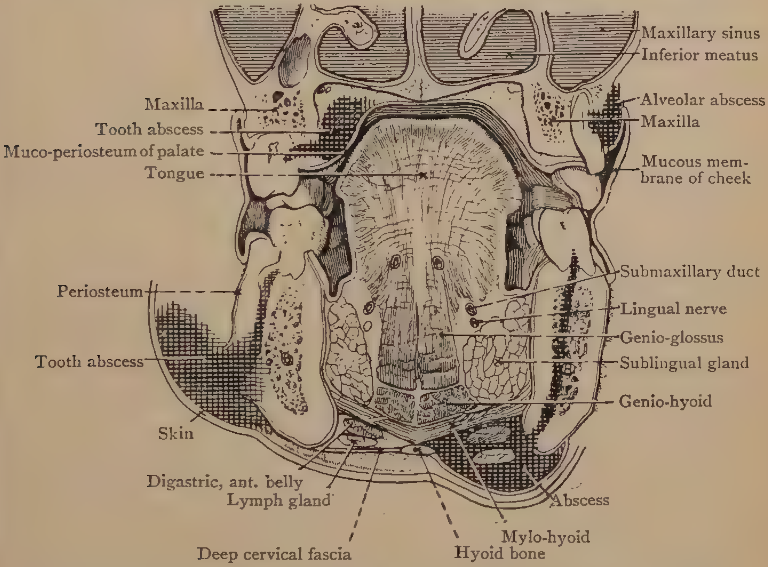

Maxillary sinus
Inferior meatus
Alveolar abscess
Maxilla
Mucous membrane of cheek
Maxilla
Tooth abscess
Muco-periosteum of palate
Tongue
Submaxillary duct
Lingual nerve
Genio-glossus
Sublingual gland
Genio-hyoid
Periosteum
Tooth abscess
Skin
Digastric, ant. belly
Lymph gland
Abscess
Mylo-hyoid
Hyoid bone
Deep cervical fascia

FIG. 54.—Frontal Section through the Mouth. Four varieties of alveolar abscess are shown. *In the maxilla*, on the right side, the pus has spread laterally, forming an abscess under the mucous membrane; on the left side, it has spread medially, forming a palatal abscess. *In the mandible*, on the right side, the pus has perforated the bone medial to the attachment of the deep cervical fascia, forming an abscess which is covered by the fascia and the skin; on the left side, the pus has perforated the bone outside the deep fascia, forming an abscess immediately under the skin.

The mucous membrane on the upper surface of the anterior two-thirds of the tongue is roughened by the projection of numerous papillæ, but on the under surface it is smooth, and the profunda veins (ranine) can be seen shining through it. Near the tip of the tongue, and embedded in the muscles on its under surface, there is a collection of mucous and serous glands, which occasionally give rise to small cysts. The under surface of the tongue is attached to the floor of the mouth by a fold of mucous membrane, termed the *frenulum.*

The submaxillary (Wharton's) duct opens on a small papilla, which is placed lateral to the point where the frenulum of the tongue joins the mucous membrane of the floor of the mouth. The *plica sublingualis,* which overlies the sublingual gland and is pierced by its ducts, runs backwards and laterally from the papilla, and can readily be seen when the floor of the mouth is examined.

The tongue is plentifully supplied with *lymph vessels,* from which arise the large collecting trunks, viz. (1) apical, (2) marginal, (3) basal, (4) central.

(1) The **Apical Lymph Vessels** drain the tip of the tongue and open into the submental lymph glands. Some, however, pass directly to join the lower anterior group of the deep cervical lymph glands at the level of the sixth cervical vertebra, and in consequence these glands may be involved at a very early stage in malignant disease of the tongue. (2) The **Marginal Lymph Vessels** drain the lateral borders of the tongue. Some of them join the submaxillary lymph glands, but the remainder run backwards and downwards to open into the deep cervical lymph glands, which lie on the carotid sheath opposite the third, fourth, and fifth cervical vertebræ. (3) The **Basal Lymph Vessels** drain the dorsum of the tongue. After running backwards towards the lower pole of the palatine tonsil, they pierce the superior constrictor, and open into the upper anterior group of the deep cervical lymph glands under cover of the posterior belly of the digastric. They communicate very freely with the corresponding vessels of the opposite side, a point of great importance clinically. (4) The **Central Lymph Vessels** drain the substance of the tongue and descend between the genio-glossi, to terminate in the lower anterior group of the deep cervical lymph glands.

Recurrence of malignant disease of the tongue usually manifests itself in the lymph glands and not in the mouth. In excision of the tongue for malignant disease it is of the greatest importance to remove all the lymph glands which drain the area involved, *i.e.* not only the proximal glands but also the whole chain of the deep cervical lymph glands.

On this account Butlin advocated the complete dissection of the anterior triangle as a routine measure. The area is exposed by two incisions, one along the whole length of the anterior border of the sterno-mastoid and the other extending from the symphysis menti to meet the first at the level of the upper border of the thyreoid cartilage. The two skin flaps are retracted and the exposed platysma is removed, since it is traversed by lymph vessels which connect the deep and superficial cervical lymph glands. For the same reason the investing layer of the deep fascia and the pretracheal fascia are both removed, as well as the stylo-mandibular ligament. All the anterior deep cervical lymph glands are taken away, and the lower part of the parotid salivary gland is removed in order to give access to the uppermost members of the group. In order to make certain that none of the submaxillary lymph glands are overlooked, the submaxillary salivary gland is also excised. Finally, after the removal of the submental lymph glands, the median raphe of the mylo-hyoids is cut through, and a search is made between the two genio-hyoid muscles.

When this operation is carried out as a preliminary step to removal of the tongue, and where there is extensive glandular infection, the external carotid artery and internal jugular vein may be resected.

On account of its rich network of lymphatics, and the presence in its substance of a quantity of loose connective tissue, the tongue may, in *acute glossitis*, suddenly become so enormously swollen as to fill up the mouth and protrude from it. Relief may be obtained by free incisions, which are made parallel to the course of the profunda linguæ (ranine) artery (*i.e.* from behind forwards). In the event of injury to the vessel, which lies on a deep plane, the hæmorrhage may be controlled by introducing the finger into the mouth and hooking the base of the tongue forwards against the mandible.

The position of *lingual dermoids* is described on p. 156.

Removal of One Half of the Tongue for malignant disease may be performed entirely through the mouth. The mucous membrane is cut through from the frenulum linguæ to the glosso-palatine arch (anterior pillar of the fauces), along the line of its reflection from the gum. A second incision is made, commencing at the frenulum, passing over the under surface of the tongue, and backwards on the dorsum in the median plane for some distance beyond the disease. The tongue is next drawn forwards from the mouth and split in the median plane. The two incisions in the mucous membrane are united by a transverse cut, and the stylo-glossus is exposed and divided as it enters the postero-lateral aspect of the tongue. The genio-glossus and the hyo-glossus are cut away from their attachments to the hyoid bone, and at this stage the lingual artery (p. 158) is secured.

In the removal of the whole tongue by the oral route, it is advantageous to split the organ and take it away in two pieces.

The **Palatine (Faucial) Tonsil** lies in the lower part of a triangular depression, the tonsillar sinus, on the lateral wall of the pharynx. The sinus is bounded in front and behind by the palatine arches (pillars of the fauces), which meet above on the posterior border of the soft palate. The *supra-tonsillar fossa* is a small depression which is situated above the tonsil in the upper part of the tonsillar sinus. Peri-tonsillar abscess gives rise to a swelling, which may involve the adjoining part of the palate as well as the supra-tonsillar fossa. It should be incised with a guarded knife, and the pus evacuated by Hilton's method. The incision is made at the point where the horizontal line corresponding to the free border of the soft palate meets the vertical line corresponding to the glosso-palatine arch (anterior pillar of the fauces).

Development.—The palatine tonsil does not begin to develop till the fourth month of fœtal life, although the tonsillar sinus, which represents a persistent part of the second visceral pouch, appears at a much earlier date. Epithelial buds, which subsequently become the tonsillar crypts, grow out from the mucous membrane on the lateral pharyngeal wall into the surrounding mesoderm. The latter becomes converted into lymphoid tissue which forms the greater part of the tonsil. Its growth in a lateral direction is obstructed by the pharyngeal aponeurosis, and so, as the organ grows, it bulges into the oral part of the pharynx. The tonsil, therefore, consists partly of mucous membrane, which covers its medial surface and lines its crypts, and partly of lymphoid tissue.

The deep surface of the normal tonsil has no definite capsule, and is only separated from the pharyngeal aponeurosis, which lines the superior constrictor, by loosely arranged areolar tissue. On this account the tonsil can readily be dragged medially from its fossa in the operation of enucleation. Hypertrophy of the lymphoid tissue of the tonsil is extremely common in childhood and youth. The organ may enlarge upwards, downwards, or medially, and may possess either a sessile or a narrow base.

Modern methods of enucleation of the tonsil endeavour to remove the whole organ, and sometimes the operation is so complete that the pharyngeal aponeurosis is in part taken away and the superior constrictor muscle is exposed.

The *blood-supply of the tonsil* is obtained from the external maxillary (facial) through its ascending palatine and tonsillar branches, from the external carotid through the ascending pharyngeal artery, and from the lingual through its dorsales linguæ branches. Severe hæmorrhage sometimes occurs after enucleation, and it has been attributed (Merkel) to injury of the external maxillary artery. This vessel, however, can only be injured when the muscular wall of the pharynx has been wounded.

If the operation is performed soon after an attack of acute tonsillitis, the tonsillar arteries are so much enlarged that they may give rise to a hæmorrhage so profuse as to suggest injury of some larger vessel.

The *lymph vessels* of the palatine tonsil join the upper anterior group of the deep cervical lymph glands. Certain members of this group (p. 137) rapidly become affected in acute tonsillitis, and in malignant disease of the palatine tonsil the glandular enlargement attracts the patient's attention before the throat condition gives rise to any marked symptoms.

The **Pharynx** is situated behind the nasal fossæ, the mouth, and the larynx. Above, it is roofed in by the base of the skull, and below, it becomes continuous with the œsophagus opposite the sixth cervical vertebra. Its lateral and posterior walls are supported by the constrictor muscles (p. 194), which are covered externally by the bucco-pharyngeal fascia. Its anterior wall is interrupted by the choanæ (posterior nares), the isthmus faucium, and the upper laryngeal aperture (Fig. 50). Below the last-named it is only separated from the muscles on the posterior surfaces of the cricoid and arytenoid cartilages by the mucous membrane.

The **Nasal Pharynx** is bounded below by the soft palate, and it can be examined by the finger, introduced through the mouth, and carried upwards behind that structure. On its *anterior wall* the posterior border of the nasal septum (p. 198) can be felt, and on either side of it the finger can be passed through the choanæ so as to touch the posterior extremities of the inferior and middle conchæ (turbinated bones). In the adult the choanæ (posterior nares) measure one inch long and half an inch wide, but in the child the relative width is much greater. In the *roof* the basilar portion of the occipital bone can be felt, and half an inch below, on the *posterior wall*, the anterior arch of the atlas can be recognised. The pharyngeal tonsil is situated on the posterior wall, and in children a proliferation of its lymphoid tissue (*adenoids*) may fill up the nasopharynx and render nasal breathing impossible. On the *lateral wall* the orifice of the auditory (Eustachian) tube leads backwards, laterally, and upwards to the tympanum (Fig. 50). The posterior lip of the opening forms a prominent elevation—the tubal projection (Eustachian cushion)—due to the cartilaginous wall of the tube, and behind it lies the pharyngeal recess (of Rosenmüller). When the orifice of the tube is occluded, *e.g.* in adenoids, the air in the tympanic cavity gradually becomes absorbed and deafness results. Inflation of the tympanum may be carried out through the pharyngeal orifice of the tube by means of a Eustachian catheter. The instrument is passed backwards along the floor of the inferior meatus until the downturned point reaches the posterior wall of the nasal pharynx. The catheter is then rotated laterally through one right angle, and in this way its point is lodged in the pharyngeal recess. It is then slowly withdrawn from the nose till the point is felt to catch on the tubal projection. Slight upward rotation of the point at this stage, accompanied by partial withdrawal, conducts it past the obstruction, and if it is now directed laterally again, the instrument passes into the orifice of the auditory tube.

The *lymph vessels* of this region join the retro-pharyngeal lymph glands (p. 116) and the upper posterior group of the deep cervical lymph glands.

The *Superior Constrictor Muscle* arises mainly from the pterygo-mandibular raphe, and is on the same plane as the buccinator (p. 180). Its upper fibres are inserted into a tubercle on the under surface of the basilar part of the occipital bone, while the rest of the muscle is inserted into a median raphe posteriorly. The *Middle Constrictor Muscle,* which overlaps the lower part of the insertion of the superior constrictor, arises from the cornua of the hyoid bone, and its fibres spread out as they pass backwards to the median raphe. The *Inferior Constrictor* arises from the sides of the thyreoid and cricoid cartilages. The lower fibres blend with the muscular wall of the œsophagus, and the upper fibres overlap the lower portion of the middle constrictor.

The constrictor muscles are supplied by the *pharyngeal plexus,* which is formed on the lateral aspect of the middle constrictor by the union of the pharyngeal branches of the vagus and glosso-pharyngeal nerves, with branches from the sympathetic trunk. The sensory portion of the plexus is distributed to the whole of the pharyngeal mucous membrane, except that covering the roof and the adjoining areas of the lateral walls, which is supplied by a branch from the spheno-palatine ganglion (p. 237).

The **Oral** and **Laryngeal Portions of the Pharynx** lie behind the mouth, the dorsum of the tongue, and the larynx. Laterally they are related to the great vessels of the neck, and posteriorly they are separated from the bodies of the upper cervical vertebræ by the retro-pharyngeal and prevertebral layers of fascia and the longus colli muscles. A retro-pharyngeal abscess (p. 116) produces a swelling of the posterior pharyngeal wall which may obstruct the passage of air during respiration, causing symptoms not unlike those associated with adenoids and hypertrophied palatine tonsils (Fig. 37).

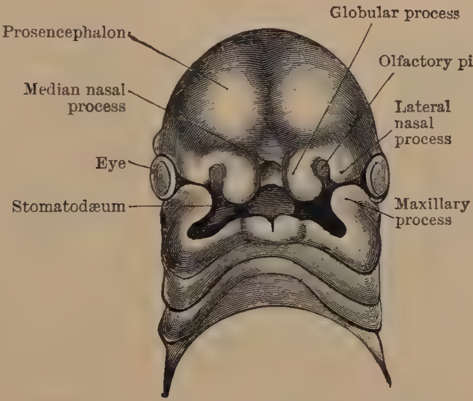


FIG. 55.—The Development of the Face.

Development of the Face and Mouth.—About the end of the third week a depression appears on the ventral surface of the embryo just behind the anterior cerebral vesicle. This is the *stomatodæum* or primitive mouth, and it is separated from the foregut by the bucco-pharyngeal membrane, which soon breaks down. An elevation appears in the forepart of the roof of the stomatodæum —the *fronto-nasal process*—and it becomes subdivided into a *median* and two *lateral nasal processes* by the *olfactory pits*, which appear on its surface and deepen to form the primitive nasal fossæ. The median nasal process projects beyond the lateral in the form of two globular processes (Fig. 55), which soon fuse to form the os incisivum and the philtrum of the upper lip. The mandibular arches (p. 152) unite to complete the floor of the stomatodæum. From the dorsal part of the mandibular arch the *maxillary process* grows forwards, but above and behind it is separated from the lateral nasal process by the naso-maxillary fissure, a part of which subsequently forms the orbit (Fig. 55).

These processes fuse so that the median nasal process gives rise to the nasal septum, the os incisivum (premaxilla), and the philtrum (middle third) of the upper lip. The lateral nasal processes form the roof and sides of the nose, while the maxillary processes form the cheeks and the remainder of the upper lip. At a later date the palatal processes grow medially from the maxillary processes, and unite with the nasal septum and with one another. As a rule, fusion occurs anteriorly at first and then spreads backwards.

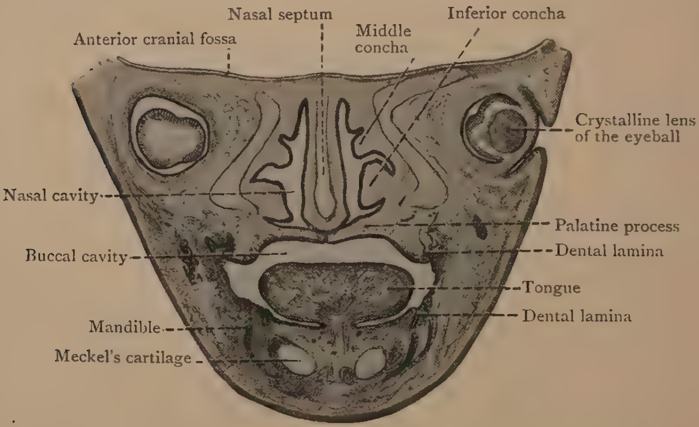

Nasal septum
Inferior concha
Anterior cranial fossa
Middle concha
Crystalline lens of the eyeball
Nasal cavity
Palatine process
Buccal cavity
Dental lamina
Tongue
Dental lamina
Mandible
Meckel's cartilage

FIG. 56.—Frontal Section through the Face of a Human Embryo at the Seventh Week.

Prior to their fusion, the lateral nasal and maxillary processes are separated from one another by a groove which extends from the region of the orbit to the olfactory pit. This groove becomes converted into the naso-lacrimal (nasal) duct, but if the fusion of the lateral nasal and maxillary processes is incomplete, the duct opens out on the surface of the face, a rare condition, known as *coloboma facialis*.

The conditions of **Harelip** and **Cleft Palate** are brought about by two or more of the above-mentioned processes failing to unite with one another. In the simplest variety, the maxillary process of one side fails to unite with the mesial nasal process on the surface only, giving rise to unilateral harelip. When the failure is more pronounced, a gap exists between the maxilla and the premaxilla in addition to the harelip. In cleft palate the palatal processes have failed to unite with one another or with the nasal septum. As the fusion occurs latest posteriorly, the bifid uvula is the simplest variety of this defect. The less complete the fusion, the further forward does the cleft extend. Thus the palatal processes may unite in front but not behind, in which case the cleft is confined to the *soft palate*. A greater degree of deformity is seen when, in addition to failure of the palatal processes to unite posteriorly, one palatal process has failed to fuse with the nasal septum. In this case the floor of the nasal fossa on one side is wanting, and the fossa communicates with the mouth. Double cleft palate is the highest degree of this deformity. It is found when the palatal processes fail to unite with one another posteriorly and both fail to unite with the median nasal process (*i.e.* nasal septum and premaxilla). The os incisivum (premaxilla) separates the two clefts anteriorly and renders the complete cleft Y-shaped. In these cases double harelip is usually present also, and the clefts extend from the surface to the tip of the uvula. In making the relief incision in the operation for cleft palate, care must be taken not to cut too far postero-medially, lest the palatine artery, which enters the posterior part of the muco-periosteal flap, be injured.

In making a prognosis with regard to the after-results of closure of a cleft palate, the shape of the arch must be taken into consideration, as the flaps are subjected to less tension when the palatal arch is pointed than when it is flat. The degree of tension may be diminished by fracturing the pterygoid hamulus (hamular process) (Stiles). By this means the tensor veli palatini (tensor palati), which winds round the bony process, is thrown out of action.

It appears from recent work (Kelsey Fry) that the scar tissue resulting from the successful closure of a cleft in the hard palate in early life exercises such powerful traction that the upper dental arch becomes greatly deformed, and satisfactory opposition of the teeth of the upper and lower jaws is rendered impossible.

Development of the Tongue.—Soon after the appearance of the branchial arches (p. 152), a small elevation, the *tuberculum* *impar*, appears in the floor of the primitive mouth. Two lateral swellings arise in connection with the mandibular arches and surround and fuse with the tuberculum impar. In this way the anterior two-thirds (or oral portion) of the tongue are formed. About the same time a transverse ridge appears behind the tuberculum impar in the region of the third arch. From this the posterior third (or pharyngeal portion) of the tongue is developed, and it soon unites with the rest of the organ.

The sensory nerve-supply of the tongue indicates the complexity of its origin. The anterior two-thirds are supplied with ordinary sensation by the lingual and with special sense (taste) by the chorda tympani, *i.e.* by the nerves of the first arch. The posterior third is supplied by the nerve of the third arch, viz. the glosso-pharyngeal.

The Nose and Air Sinuses.—The development of the nose has already been outlined on p. 195. The lateral wall of the nasal cavity bears the three *conchæ* (*turbinated bones*), which project medially and downwards so as to separate the three meatuses of the nose. The mucous membrane on the lateral wall is provided with a freely distensible submucous layer, so that such conditions as hypertrophic rhinitis can readily occur. Over the septum, which forms the medial wall of the cavity, the mucous membrane is firmly bound down. The nerves of ordinary sensation are all derived from the spheno-palatine (Meckel's) ganglion, except the nasal branch, from the ophthalmic, which ramifies on the septum. The olfactory nerves are distributed to the mucous membrane in the upper third of the cavity.

Into the forepart of the **Inferior Meatus** the *naso-lacrimal duct* opens under cover of the inferior concha. The **Middle Meatus** receives the openings of the infundibulum from the *frontal air sinus*, the *anterior* and *middle ethmoidal cells*, and the *maxillary sinus* (*antrum of Highmore*) (Fig. 57). The two former open into the hiatus semilunaris, a curved depression on the lateral wall. The *bulla ethmoidalis*, which forms a part of the ethmoid bone, projects into the middle meatus immediately above the hiatus. It contains the middle ethmoidal cells, which open at its upper border. The **Superior Meatus** receives the *posterior ethmoidal air-cells*; the sphenoidal air-cells open into a small depression lying above and behind the superior concha, termed the recessus spheno-ethmoidalis.

The **Nasal Septum** is formed posteriorly by the vomer, antero-superiorly by the perpendicular plate of the ethmoid, and antero-inferiorly by the septal cartilage. *Deviation of the septum* rarely occurs before the seventh year. It may involve the cartilage only, or both bones and cartilage may be deviated to one or other side. It may be caused by excessive growth of the vomer and the perpendicular plate of the ethmoid, and the septum buckles along the line of their articulation. Overgrowth of the septal cartilage alone is obstructed posteriorly by the osseous septum, in which its margins are firmly fixed. In this case, too, deviation occurs, but only the cartilaginous part of the septum is affected. Deviation of the septum may result from trauma, and it tends to occlude the nasal fossa into which it projects.

Fracture of the nasal bone occurs about half an inch above its lower margin and usually leads to lateral displacement of the nose; but if, in addition, the perpendicular plate of the ethmoid is broken, the nose is depressed backwards. These fractures are usually compound through the mucous membrane, and surgical emphysema is apt to follow if the patient blows his nose. Owing to the plentiful blood-supply of the parts, rapid union occurs, and it is therefore important that the fragments should be replaced as soon as possible after the accident.

The **Maxillary Sinus (Antrum of Highmore)** appears during the third month of fœtal life as a budding-out from the mucous membrane of the nasal cavity in the region of the middle meatus. It grows into the maxillary process, and the maxillary bone is formed around it.

The maxillary sinus is roughly pyramidal in shape. Its apex is situated at the zygomatic (malar) process, and its base forms the lateral wall of the nasal cavity. Above, it is roofed in by the orbital surface of the maxilla, which is channelled by the infra-orbital nerve. The postero-lateral wall of the sinus forms one of the boundaries of the infra-temporal (zygomatic) fossa, and its antero-lateral wall is depressed externally to form the canine fossa. Inferiorly, the sinus is bounded by the alveolar border, and the roots of the molar and premolar teeth form projections in its floor. The walls are lined by muco-periosteum, which is continuous with the mucous membrane of the middle meatus of the nose through the opening of the sinus, which is placed in the upper part of its medial wall.

Infection may reach the maxillary sinus directly from the middle meatus, or it may ascend through the floor from carious teeth. When pus is present in the sinus, the natural method of drainage into the middle meatus is far from efficient, as the sinus can only be emptied completely when the head is bent over to the opposite side. When the patient lies down, the pus

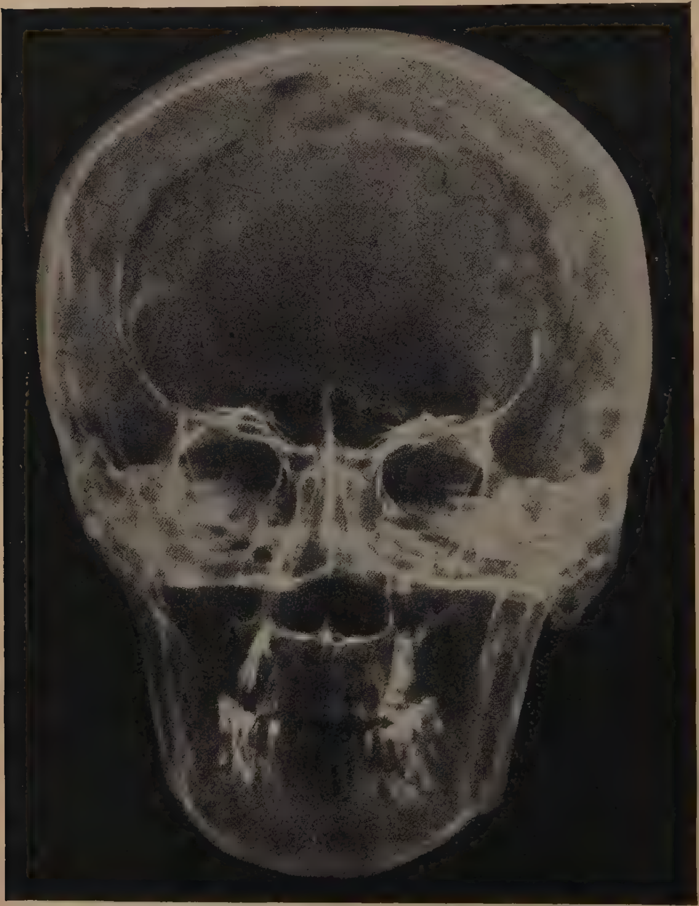


FIG. 57.—Radiogram of Skull, showing normal Maxillary and Frontal Sinuses.

trickles down the middle meatus and passes into the nasopharynx. Assistance in the diagnosis is obtained by the use of transillumination and radiograms. In both, the diseased sinus is more opaque than the healthy one (Fig. 58).

The sinus may be approached for the purpose of drainage in three ways: (*a*) The tooth at fault may be extracted and a hole may be drilled upwards through its socket into the sinus. (*b*) The lateral wall of the inferior meatus of the nose may be broken down and the sinus opened into through its base. (*c*) The upper lip may be everted and the muco-periosteum incised over the canine fossa. A hole is then drilled through the bone, lateral to the ridge produced by the root of the canine tooth. If the drill were applied to the medial side of the ridge, the inferior meatus of the nose would be opened into instead of the sinus.

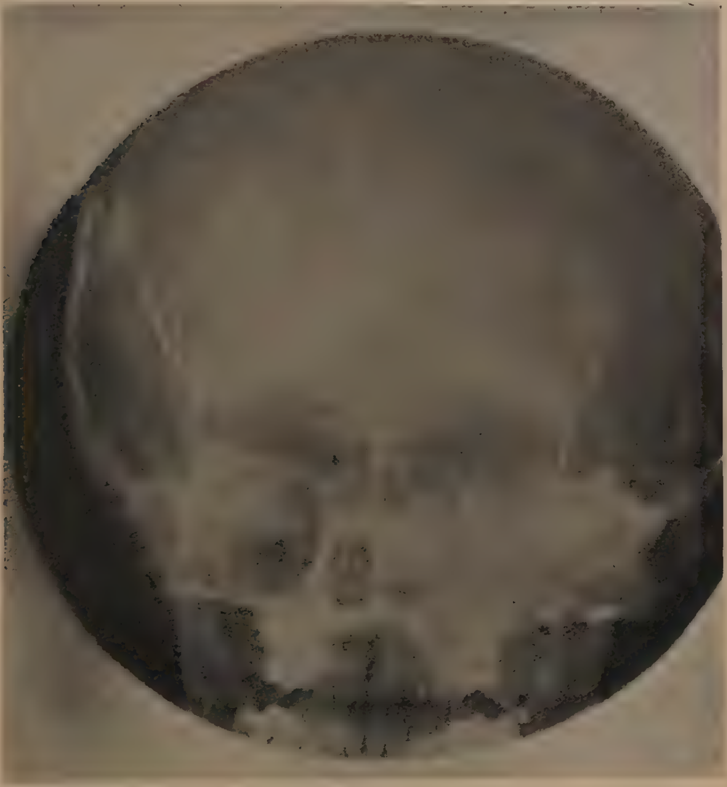


FIG. 58.—Empyæma of Maxillary Sinus.

Malignant tumours arising from the muco-periosteal lining of the maxillary sinus are not uncommon, and the symptoms to which they give rise depend on the direction in which they grow. If the roof of the sinus is pushed upwards, the eye becomes more prominent, and neuralgia may occur from pressure on the infra-orbital nerve. The pain in this case may be referred over the whole distribution of the trigeminal. If the pressure is mainly exerted on the medial wall, the naso-lacrimal duct is obstructed, causing epiphora. As the tumour grows, it pushes its way into the nasal fossa and blocks that side of the nose. Forward growth obliterates the canine fossa, and downward growth invades the palate and gives rise to a swelling in the roof of the mouth. Owing to the depth of the infra-temporal fossa, backward growth may go on for some time before the presence of a tumour is suspected.

Eradication of malignant disease in this region necessitates the **removal of the whole maxilla.** The reader should follow on the skull the description given below, as it is important that the method of approach should be clearly understood, since it may also be employed for removal of naso-pharyngeal fibro-sarcomata.

Preliminary laryngotomy and temporary occlusion of the external carotid artery materially assist the surgeon in performing this operation.

The *incision* begins just below the medial palpebral (internal tarsal) ligament, which can be felt quite distinctly at the medial angle of the eye, when the lateral palpebral commissure (external canthus) is drawn laterally. It passes down the side of the nose, round the ala nasi, and down through the upper lip into the mouth in the median line. The horizontal part of the incision runs along the lower margin of the orbit to the zygomatic bone, and is kept parallel to the branches of the facial nerve (p. 182). If the external carotid has not been occluded, the cut branches of the external maxillary artery bleed profusely, as the incision is at once carried right down to the periosteum. The flap is rapidly elevated from the maxilla, and the reflection of the mucous membrane from the gum to the cheek is divided, so that the flap may be turned down, kinking the external maxillary artery, and thus arresting the hæmorrhage. In elevating the flap, the orbicularis oculi, the zygomaticus, and several other facial muscles are cut through, and the infra-orbital nerve and its artery are divided as they leave the foramen.

In the next step, the periosteum is elevated from the orbital surface of the maxilla. It must be preserved, because it subsequently forms a support for the eye, and because it will prevent any possible sepsis from entering the orbit. Further, in this way the origin of the inferior oblique muscle of the eye can be preserved intact. The periosteum is elevated over the floor of the orbit until the inferior orbital (spheno-maxillary) fissure is reached. A Gigli saw is passed down into the fissure and brought out again below the zygomatic bone, and the maxilla is then divided.

The attachment of the lateral nasal cartilage to the frontal (nasal) process of the maxilla is divided, and the nose can then be displaced to the opposite side. One blade of a pair of large bone forceps is passed backwards into the upper part of the nasal cavity, and the other blade into the orbit towards the medial end of the inferior orbital fissure. When the blades are approximated, the frontal process of the maxilla, the lacrimal bone, and the ethmoidal labyrinth (lateral mass) are divided, and the naso-lacrimal duct is torn through. To detach the bone from its attachments posteriorly, the flap must be well retracted, so that a chisel may be inserted into the groove between the maxilla and the pterygoid process (plates) of the sphenoid. A slight blow will effect the separation. The maxilla is still held in place by the hard palate, which has yet to be divided. The mucous membrane is cut through from the original incision in the lip backwards across the gum and along the inner border of the alveolus, and it is continued round the last molar tooth to join the incision along which it was previously split between the cheek and the gum. The palatal aponeurosis and the velum palatinum (soft palate) are freed from the posterior margin of the hard palate, and a saw is passed through the anterior nares and made to cut downwards into the mouth. The maxilla may now be lifted out with the finger and thumb, as it is only attached to a few fibres of the internal pterygoid and the proximal part of the infra-orbital nerve. At this stage severe hæmorrhage will occur from the alveolar (dental) branches of the internal maxillary artery if the preliminary step of temporary occlusion of the external carotid has not been adopted.

The **Zygomatic (Malar) Bone** may be fractured by direct violence and depressed inwards. It may be levered back into position by a strong periosteum detacher, passed upwards through an incision in the mucous membrane along the line of its reflection from the cheek to the gum. This fracture may be associated with fracture of the maxilla, in which case the maxillary sinus is opened into, and there is danger of surgical emphysema occurring, unless the patient is warned not to blow his nose.

The **Frontal Air Sinus** arises soon after birth as an outgrowth of the mucous membrane lining the middle meatus of the nose, but it does not begin to enlarge until the seventh year. It grows upwards and backwards, and penetrates into the anteromedial portion of the orbital part of the frontal bone. The two sinuses are separated from one another by a thin septum, which, although median below, is usually deflected to one or other side above. According to Logan Turner the average dimensions of the frontal sinus are: Height, from the frontomaxillary suture upwards, 1¼ inches; width, from the septum laterally, 1 inch; depth, from the surface backwards, between the orbit below and the anterior cranial fossa above, ¾ inch. As the cavity is lined with muco-periosteum, which is continuous with the nasal mucosa, the sinus may be infected secondarily to nasal mischief. On the other hand the anterior and middle ethmoidal cells are frequently infected by direct spread from a diseased frontal sinus. The infundibulum, or duct of the sinus, is not disadvantageously situated for drainage, but, owing to small bony septa which may be present, loculi are sometimes formed, and they prevent pus from draining away into the nose.

Empyæma of the Frontal Sinus can be recognised by transillumination or radiograms (Fig. 59), and, by these means, the position of the septum between the two sinuses can be ascertained. This detail is of extreme importance, as the surgeon must be certain of opening the infected sinus only. Retained pus in the frontal sinus may find its way through the floor into the orbit, and point at or near the medial palpebral commissure (inner canthus).

The sinus is approached from in front by an *incision* which follows the eyebrow, and may be extended medially and downwards on to the nose. After it has been opened up, the infundibulum is enlarged so as to permit the passage of a drainage tube down into the nose. In this process the anterior ethmoidal cells, which are usually affected, are broken down, and the anterior extremity of the middle concha (turbinated bone) will probably require to be removed.

Fractures of the frontal bone may open into the frontal sinus without involving the cranial cavity. In these cases, as in fracture of the maxilla, there is every likelihood of surgical emphysema, unless the patient is warned against blowing his nose.

The **Ethmoidal Air-Cells** are all situated in the ethmoidal labyrinth (lateral mass), and are only separated from the orbit by the thin lamina papyracea (os planum). On the medial surface of the labyrinth are the projections which form the superior and middle conchæ (turbinated bones). The anterior and middle ethmoidal cells open into the middle meatus, and the posterior open into the superior meatus of the nose.

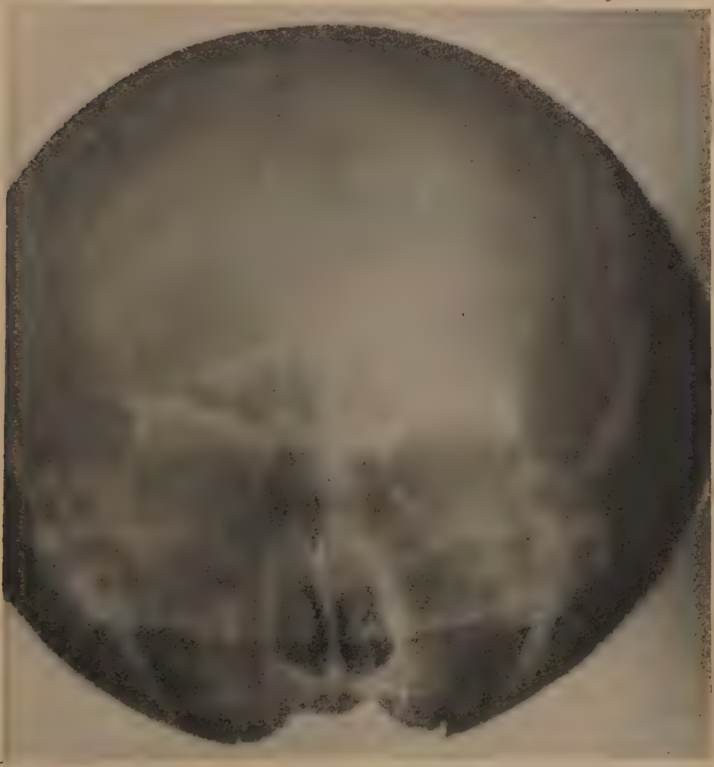


FIG. 59.—Empyæma of the Left Frontal Sinus.

The **Sphenoidal Sinuses** are situated in the body of the sphenoid and immediately below the fossa which lodges the hypophysis (pituitary body). They are separated from one another by a septum, which is usually deviated to one or other side of the median plane. When these sinuses become infected, the condition may spread upwards in front of the hypophysis (pituitary body) and affect the optic chiasma, which lies above the forepart of the body of the sphenoid, thus giving rise to disturbance of vision. Collections of pus in the sphenoidal sinus can only be evacuated properly by removal of its anterior wall. This is reached through the posterior ethmoidal cells, which are usually involved, by removal of the middle and superior conchæ (turbinated bones).

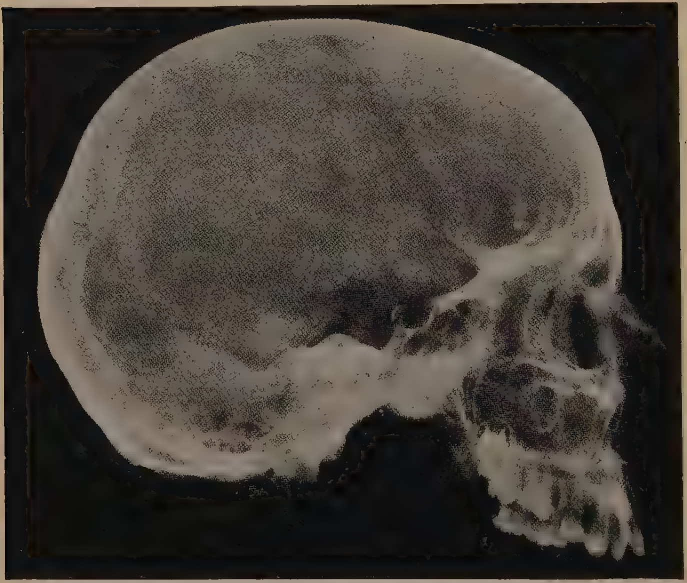


FIG. 60.—Lateral Radiogram of Skull. The relation of the sphenoidal sinuses to the hypophyseal fossa (sella turcica) is well shown.

Tumours of the Hypophysis (Pituitary Body) are occasionally removed through the sphenoidal sinuses. A somewhat U-shaped incision is made round the nose, which is turned upwards after the nasal septum has been removed and the lateral nasal cartilages divided.

By taking away the superior and middle conchæ, better access can be obtained. At a depth of 2½ inches from the surface the resistance of the anterior wall of the sphenoidal sinuses is encountered, and the wall is lightly chiselled through. The septum between the sinuses is removed, and the postero-superior wall, which is usually much thinned, is opened very carefully in the middle line, and the tumour is removed piecemeal. The lateral relations of the hypophysis (p. 229) are pushed aside by the growth of the tumour and run little risk of injury. Lateral radiograms (Fig. 60) clearly demonstrate the size of the fossa hypophyseos (sella turcica) and it is definitely enlarged in these cases. See also p. 240.

THE EYE.

The Eyelids.—The eyelids are supported by the *tarsi* (*tarsal plates*), which consist of condensed fibrous tissue, and from their margins the medial and lateral palpebral (tarsal) ligaments extend to the medial and lateral borders of the bony orbit. Each tarsus is separated from the skin by a muscular layer and subcutaneous tissue, and the latter, being very loosely arranged, is readily distended by effusions. Further, the skin of the eyelid is so thin that an effusion of blood into the subcutaneous tissue becomes apparent at once as a "black eye." Numerous sebaceous glands are situated in the free margin of the eyelid, and, when they become involved in suppurative inflammation, they give rise to the condition known as a "stye."

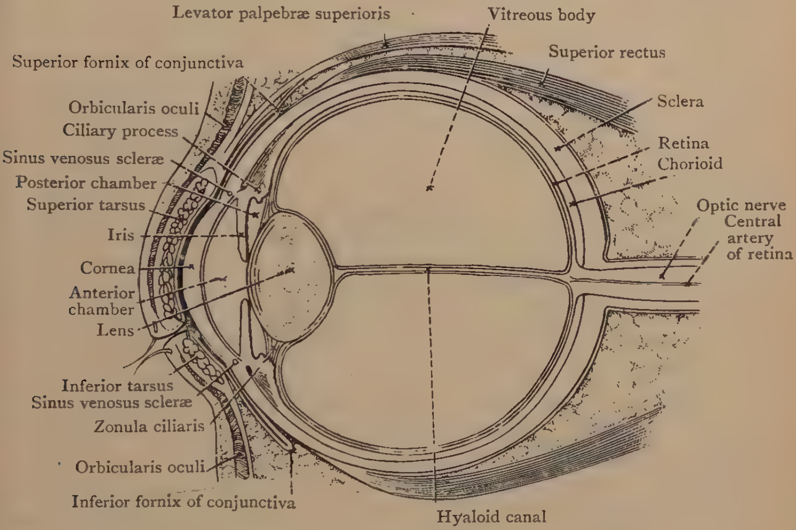

Levator palpebræ superioris
Vitreous body
Superior fornix of conjunctiva
Superior rectus
Sclera
Orbicularis oculi
Ciliary process
Retina
Sinus venosus scleræ
Chorioid
Posterior chamber
Superior tarsus
Optic nerve
Central artery of retina
Iris
Cornea
Anterior chamber
Lens
Inferior tarsus
Sinus venosus scleræ
Zonula ciliaris
Orbicularis oculi
Inferior fornix of conjunctiva
Hyaloid canal

FIG. 61.—Diagram of a Sagittal Section through the Eye.

The deep surfaces of the lids are lined by a mucous membrane, **the Conjunctiva**, which is reflected from them on to the anterior surface of the eyeball. The lines along which this reflection takes place are termed the superior and inferior *fornices* of the conjunctiva. Where it covers the cornea, the conjunctiva is represented by a translucent layer of stratified epithelium. The upper eyelid may be everted along the upper border of the tarsus, and in this way the conjunctiva on its surface may be exposed for the purpose of removing foreign bodies. Eversion of the lid brings into view the *tarsal* or *Meibomian glands*, which appear as yellow streaks near its free margin. It is therefore from this surface that tarsal cysts, which are simply obstructed tarsal glands, are excised. The sensory nerves of the conjunctiva are all derived from the trigeminal (mainly supra-orbital and infra-orbital branches). Blepharo-spasm and lacrimation may be caused reflexly by the presence of foreign bodies or by an inflammatory condition of the conjunctival sac. In paralysis of the trigeminal, conjunctivitis or corneal ulceration frequently results from the presence of particles of dirt, which are unrecognised owing to the loss of sensibility. Ultimately, the intra-ocular structures become affected and pan-ophthalmitis ensues.

The *arterial supply* of the lids is derived from the ophthalmic artery. The corresponding *veins* communicate with the ophthalmic veins, which join the cavernous sinus, and also with the superficial temporal and anterior facial veins. On account of the existence of this double channel of return, effusions into the eyelids are absorbed with great rapidity. Both lids contain a rich network of *lymph vessels*, and, as a result, drugs placed in the conjunctival sac, in the form of lamellæ, are quickly absorbed. From the lateral half of the lids the lymph vessels pass to the anterior auricular lymph gland, while those from the medial half follow the course of the anterior facial vein, and pass through the facial lymph glands, before terminating in the submaxillary lymph glands.

The tarsi are connected to the upper and lower margins of the orbit by fibrous tissue, which forms a sheet sufficiently strong to delay a retro-tarsal hæmorrhage from passing forwards into the subcutaneous tissue of the eyelid. In fracture of the skull involving the roof of the orbit, the hæmorrhage appears first under the margins of the conjunctiva, and then spreads in a fan-shaped manner towards the cornea. The blood remains red owing to the thinness of the conjunctiva and the consequent transfusion of oxygen from the air. The hæmorrhage may descend between the superior tarsus and the conjunctiva, and subsequently appear at the margin of the upper eyelid. Finally, it may ascend on the outer surface of the tarsus and become subcutaneous.

Subconjunctival hæmorrhage may arise from the conjunctival vessels as the result of a blow on the eye, but in these cases the hæmorrhage begins near the cornea.

The **Lacrimal Gland** lies in contact with the antero-lateral part of the roof of the orbit. Its posterior portion rests on the eyeball, but anteriorly it is in contact with the superior fornix of the conjunctiva, and this portion of the gland can just be made out when the upper eyelid is everted. Numerous small ducts leave the gland and open into the conjunctival sac near the superior fornix. The tears pass across the eyeball by the action of gravity, aided by surface tension and the periodic contractions of the orbicularis oculi, and reach the *puncta* on the medial side. These are small openings placed on the summits of papillæ, which are situated on the free margins of the lids near their medial extremities. They are kept in apposition with the conjunctiva by the action of the inferior tarsal (tensor tarsi) muscle, which is a part of the orbicularis oculi, and is supplied by the facial nerve. The condition of *epiphora* results from the paralysis of this muscle. The puncta lead into the *lacrimal ducts,* which at first run for a short distance at right angles to the lid margins, and then turn medially to enter the lacrimal sac (Fig. 62).

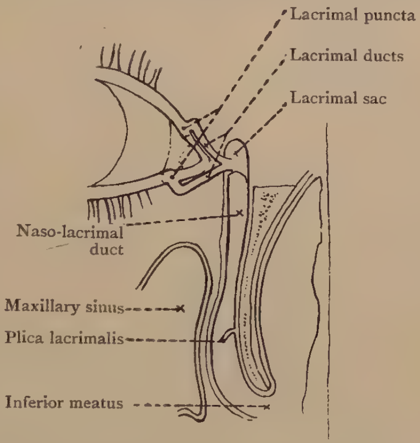


FIG. 62.—Diagram of the Naso-lacrimal Duct and its Connections.

The **Lacrimal Sac** lies behind the medial palpebral (tarsal) ligament. Abscesses in the sac should be incised just below the ligament, the position in which they usually point, and lateral to the termination of the external maxillary artery (Stiles). The upper end of the sac is blind, but below it narrows to form the *naso-lacrimal duct*, which opens into the inferior meatus of the nose. This duct is about half an inch long, and its lower end is protected by a fold of mucous membrane (the plica lacrimalis). In cases of epiphora where a blockage of the naso-lacrimal duct is suspected, a probe may be passed along it from its upper end. The lower lid is everted, and the probe is entered at the punctum and passed in for a short distance. It is then passed medially along the duct into the lacrimal sac until its medial wall is encountered. The hand is then elevated so that the point of the probe is made to pass downwards and slightly backwards and laterally into the nose. The direction of the naso-lacrimal duct is indicated by a line joining the medial palpebral commissure (inner canthus) to the interval between the first molar and the second premolar tooth.

The Orbit and Eyeball.—The **Fascia Bulbi (Capsule of Tenon)** is a layer of fascia which almost completely surrounds the eyeball, and is continuous with the sheath of the optic nerve behind. Anteriorly, it lies deep to the conjunctiva and terminates at the corneo-scleral junction. The bellies of the orbital muscles lie outside the fascia, but their tendons pierce it to gain insertion into the sclera, and the fascia is prolonged backwards upon them to fuse with the muscle sheaths. These prolongations are particularly strong in relation to the lateral and medial rectus muscles, and they are connected to the walls of the orbit, an arrangement which checks lateral and medial rotation of the eye (*check ligaments*). They are connected to one another by a thickened part of the fascia bulbi which lies below the eye, forming the suspensory ligament of Lockwood. It is this band, together with the orbital periosteum, which supports the eyeball after excision of the maxilla (p. 202).

The Muscles of the Orbit.—The *Levator Palpebræ Superioris* lies immediately under the orbital roof. It is supplied by the oculo-motor nerve, and when that nerve is paralysed the condition of ptosis results. The *Superior Rectus* rotates the eyeball upwards and medially. It acts in unison with the *Inferior Oblique*, which rotates the eyeball upwards and laterally. *Both* are supplied by the oculo-motor nerve. The *Inferior Rectus* rotates the eyeball downwards and medially, and acts in unison with the *Superior Oblique*, which rotates it downwards and laterally. The former is supplied by the oculo-motor and the latter by the trochlear nerve. The *Lateral Rectus*, supplied by the abducent nerve, and the *Medial Rectus*, supplied by the oculo-motor, produce lateral and medial rotation of the eyeball.

Motor Nerves of the Orbit.—The *Oculo-motor* (third cerebral) nerve supplies all the orbital muscles except the superior oblique and the lateral rectus. In addition it gives off the short (motor) root of the ciliary (lenticular) ganglion, and in this way supplies the ciliary muscle and the sphincter pupillæ. In *complete paralysis of the oculo-motor nerve*, the pupil is widely dilated by the dilatator pupillæ (supplied by the sympathetic) and does not react to light. The power of accommodation to distance is lost, and ptosis is present. Owing to the unopposed action of the lateral rectus, which is not involved, a divergent strabismus results, and the patient carries his head rotated to the opposite side in order to compensate for his disability, unless ptosis is so pronounced as to prevent vision. When paralysis of the oculo-motor nerve is *incomplete*, the branch to the sphincter pupillæ most commonly escapes.

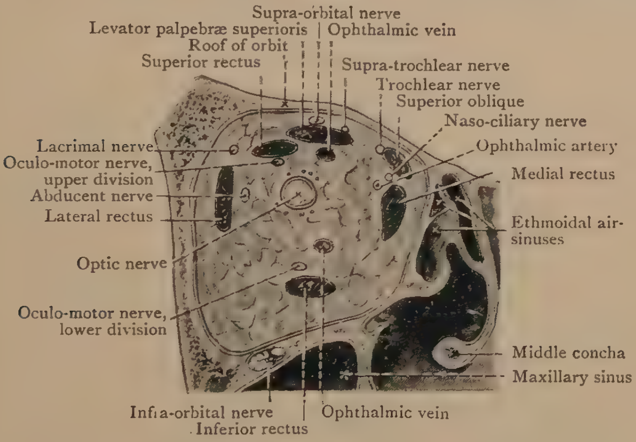

Supra-orbital nerve
Levator palpebræ superioris
Ophthalmic vein
Roof of orbit
Superior rectus
Supra-trochlear nerve
Trochlear nerve
Superior oblique
Naso-ciliary nerve
Ophthalmic artery
Lacrimal nerve
Oculo-motor nerve, upper division
Abducent nerve
Lateral rectus
Medial rectus
Ethmoidal air-sinuses
Optic nerve
Oculo-motor nerve, lower division
Middle concha
Maxillary sinus
Infra-orbital nerve
Ophthalmic vein
Inferior rectus

FIG. 63.—Frontal Section through the Orbit, to show the relative positions of the Muscles, Vessels and Nerves.

The *Trochlear* (*Fourth Cerebral*) *Nerve* supplies the superior oblique only. Paralysis of this nerve produces diplopia, when the patient looks downwards, because, while pure downward rotation is possible in the sound eye, the inferior rectus imparts a medial as well as a downward direction to the eye on the affected side, and the superior oblique, which should counteract the medial rotation, is paralysed.

The *Abducent (Sixth Cerebral) Nerve* supplies the lateral rectus muscle. When it is paralysed, the medial rectus is unopposed and a convergent strabismus results. In an endeavour to compensate for this disability, the patient carries his head rotated to the affected side.

In the intracranial part of their course the motor nerves of the orbit may be pressed on by the exudate of a basal meningitis (p. 229), by hæmorrhage following fractures of the base of the skull, or by thrombosis of the cavernous sinus as they lie in its lateral wall (p. 229).

Tenotomy of the Ocular Tendons is performed in cases of strabismus which are due to congenital shortening of the medial or lateral rectus muscles. An incision is made through the conjunctiva near the margin of the cornea, and the underlying fascia bulbi (capsule of Tenon) is opened. A blunt hook may be inserted through the wound, and the desired tendon can be drawn forwards and divided.

The *Ophthalmic Artery* is a branch of the internal carotid. It supplies the muscles of the orbit, the lacrimal gland, and the eyelids. Ciliary branches supply the eyeball, and the arteria centralis retinæ, which runs forwards in the optic nerve, is distributed to the retina.

The *Ophthalmic Veins* communicate with the pterygoid venous plexus through the inferior orbital (spheno-maxillary) fissure, and with the anterior facial vein (p. 179). They pass backwards through the superior orbital (sphenoidal) fissure and join the cavernous sinus.

The Eyeball.—The **Sclera**, a strong fibrous membrane, forms the outermost coat of the eye. Anteriorly, it lies deep to the conjunctiva and the fascia bulbi and blends with the cornea. It is supplied by branches from the ciliary arteries, and as these vessels approach the corneo-scleral junction they send out branches into the episcleral tissue, which form anastomosing loops close to the margin of the cornea. From these loops numerous small straight branches pass into the periphery of the cornea, where they anastomose with one another. In inflammation of the sclera these vessels become visible, and form the "zone of ciliary injection."

The **Cornea** consists mainly of modified connective tissue. Except at its extreme edge, it is non-vascular, but it is well provided with spaces containing lymph, on which it depends for its nutrition. The lymph is drained from the cornea by the *sinus venosus scleræ* (*canal of Schlemm*).

In repair of inflammatory conditions of the cornea, the newly formed connective tissue, not being specialised, may cause opacities, which vary in degree from nebulæ to leucoma. *Iridectomy* may be of value in certain cases, as it offers a larger aperture for the transmission of light.

Internal to the sclera is the **Chorioid**, which supports the ciliary vessels and contains numerous pigment cells. Anteriorly, the chorioid is continuous with the **Ciliary Body** and the **Iris.** The iris separates the anterior from the posterior chamber of the eye. Its peripheral attachment is continuous behind with the ciliary body and in front with the deepest layer of the cornea, which it meets at an acute angle. A circular channel, the sinus venosus scleræ (of Schlemm), is placed in the corneo-scleral junction immediately opposite the angle between the iris and the cornea (Fig. 61). The sinus is surrounded by numerous lymph spaces, through which the aqueous humour and the lymph from the cornea communicate with it and indirectly with the ciliary veins. Obliteration of this angle by the formation of adhesions prevents the proper drainage from the aqueous humour, and causes increased intra-ocular tension and glaucoma. The iris is richly supplied with blood, and the ciliary arteries form anastomosing circles at its free and attached margins.

The optic nerve pierces the retina at a point a little medial to the posterior pole of the eyeball. The *papilla of the optic nerve* (*optic disc*) is the physiological "blind spot" of the retina. With the aid of the ophthalmoscope, the central artery of the retina can be seen on the papilla breaking up into its terminal branches. In all mammals which have binocular vision, the point on the retina through which the antero-posterior axis of the eyeball passes is highly specialised, and is known as the macula lutea.

The *Vitreous Body*, which occupies the greater part of the posterior chamber of the eye, is surrounded by the hyaloid membrane. In front, the membrane is attached to the ciliary body, and divides to form the suspensory ligament which encloses the *Crystalline Lens*. When the ciliary muscle, which is contained in the ciliary body, contracts, the suspensory ligament is drawn forwards, and the pressure which it exerts on the anterior surface of the lens is diminished. As a result, this surface becomes more convex, and diverging rays of light become focussed on the retina.

The diameter of the crystalline lens is one-third of an inch, and this measurement must be remembered in making the incision in the corneo-scleral junction for its removal.

THE AUDITORY APPARATUS.

Development.—The outer cartilaginous portion of the *external acoustic meatus* is derived from the dorsal part of the first visceral cleft, and the *auricle* is formed by the development and fusion of several tubercles, which arise from the mandibular and hyoid (first and second) arches. This double origin is indicated in the adult by the double nerve supply from the auriculo-temporal and great auricular nerves (pp. 110, 178). Owing to faulty union of the various tubercles with one another, pre-auricular fistulæ may occur. The interval between the helix and the tragus is the commonest site of this congenital deficiency, and it is said to indicate the line of union between the first and second arches.

The *Tympanum* or *Tympanic Cavity* and the *Auditory* (*Eustachian*) *Tube* are the remains of the first visceral pouch (Fig. 46). They are enclosed in the temporal bone, which consists of three pieces at birth. The *Petromastoid Portion* encloses the internal ear, and forms the medial part of the roof and the medial wall of the tympanum, the osseous part of the auditory tube, and the tympanic (mastoid) antrum. The *Squamous Portion* forms part of the lateral wall of the skull and of the tympanum, and the upper part of the osseous external acoustic meatus. It also forms the lateral wall of the tympanic antrum and the lateral part of the roof of the tympanum. The *Tympanic Ring* forms the remainder of the osseous external meatus. Although the tympanic antrum is present at birth, the mastoid process does not begin to develop until the end of the second year, and the mastoid air-cells begin to appear as outgrowths from the antrum at the same period.

The **External Acoustic Meatus** leads from the concha to the membrana tympani. Its lateral cartilaginous portion is first directed medially, forwards and upwards, and then, at a distance of about a quarter of an inch from the surface, medially and backwards to meet the osseous portion of the meatus, which is directed medially, downwards and forwards. The membrana tympani is obliquely placed so that the lower and anterior walls of the canal are definitely longer than the upper and posterior. The total length of the meatus is about one inch, and its narrowest part is found at three-quarters of an inch from the surface. In the examination of the tympanic membrane the canal is straightened by drawing the auricle upwards and backwards. This procedure brings the cartilaginous portion into line with the osseous portion, but in the infant the auricle must be drawn downwards and backwards, as the canal is almost entirely cartilaginous, and the outer surface of the membrana tympani is directed mainly downwards.

The external acoustic meatus is lined by modified skin, which is reflected over the outer surface of the tympanic membrane. It is firmly bound down to the periosteum and perichondrium, and therefore septic infections of the canal, although causing little swelling, give rise to severe pain. Chronic inflammatory processes may stimulate the periosteum to such an extent that the new bone may occlude the canal almost entirely. The cuticular lining is supplied by branches from the auriculotemporal nerve (p. 178) and the auricular branch of the vagus. Stimulation of the latter nerve, by foreign bodies or collections of wax, may produce symptoms so divergent as cough (internal laryngeal nerve, p. 163) and dyspepsia (terminal branches of vagus, p. 301). Similar irritation of the auriculo-temporal nerve gives rise to pain, which may be referred to the side of the head, to the teeth of the mandible, etc.

The cuticular lining of the canal possesses numerous ceruminous glands; and the wax which they secrete is normally carried to the exterior by the movements of the mandibular condyle, which presses against the anterior wall of the meatus. Sudden deafness sometimes follows the entrance of water into the canal, as it is readily absorbed by the wax, which swells up in consequence.

The **Membrana Tympani** lies at the bottom of the external acoustic meatus, and forms the greater part of the lateral wall of the tympanic cavity. It consists of an outer cutaneous, an inner mucous, and an intermediate fibrous layer. It is very obliquely placed, so that its outer surface looks laterally, downwards and slightly forwards, *i.e.* the antero-inferior portion is furthest removed from the surface.

When a normal tympanic membrane is examined with the aid of reflected light, a well-marked depression, the *umbo*, can be recognised at a little below its centre. When the auditory tube is obstructed the air in the tympanum becomes absorbed, and the normal concavity is accentuated. The *handle of the malleus*, which is attached to the fibrous layer of the membrane, can be traced upwards and forwards from the umbo to a small prominence, which is produced by the lateral (short) process of the malleus. From this point the anterior and posterior malleolar folds diverge in an upward direction, and bound the flaccid part of the membrane (Fig. 64). The *crus longum* (*long process*) *of the incus* may be discerned lying behind and parallel to the handle of the malleus, though it lies on a deeper plane. A cone of reflected light extends from the umbo over the antero-inferior part of the membrane, and serves as a guide to the site of puncture in the operation of *paracentesis tympani*, which is carried out through the postero-inferior quadrant. This part of the membrane is selected because it is furthest removed from the handle of the malleus and the chorda tympani, and because it affords good drainage. The nerve runs downwards and forwards across the deep surface of the membrane, lateral to the crus longum of the incus, but medial to the neck of the malleus. The point of the knife must not be pushed too deeply through the membrane as the tympanum is only one-eighth of an inch wide at this point, and the fenestra of the cochlea (fenestra rotunda), which lies on its medial wall, may be injured.

The **Tympanum** is about half an inch in length, and varies from a tenth to a sixth of an inch in width. Its uppermost part, known as the *Epitympanic Recess* (*Attic*), lies above the level of the tympanic membrane, and contains the head of the malleus and the body of the incus.

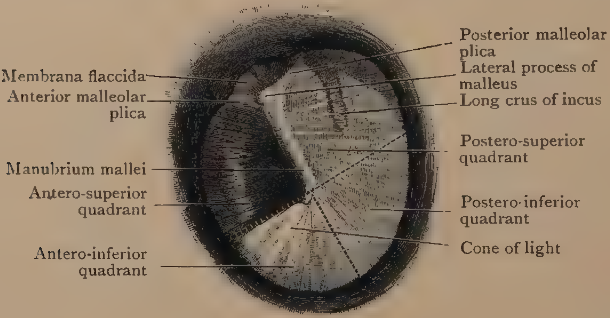

Membrana flaccida
Anterior malleolar plica
Manubrium mallei
Antero-superior quadrant
Antero-inferior quadrant
Posterior malleolar plica
Lateral process of malleus
Long crus of incus
Postero-superior quadrant
Postero-inferior quadrant
Cone of light

FIG. 64.—Left Tympanic Membrane (as viewed from the external acoustic meatus). × 3.

The **Anterior Wall** of the tympanum is formed by a thin plate of bone, which separates the tympanic cavity from the carotid canal. In the lateral part of this wall is situated the opening of the auditory tube, which leads downwards, forwards, and medially to the nasal pharynx. In the child the direction of the tube is practically horizontal, the downward inclination being very slight. The **Roof** is formed by the *tegmen tympani*, which separates the tympanum, the auditory tube, and the tympanic (mastoid) antrum from the middle cranial fossa and the temporal lobe of the brain. Its lateral border corresponds to the line of the petro-squamous suture, which may remain unossified until the end of the second year. Up to that age inflammatory conditions of the brain or meninges may be caused by the upward spread of infection from the tympanum along the veins which traverse the suture and terminate in the superior petrosal sinus. The narrow **Floor** of the tympanum is formed by the bone of the jugular fossa, and lies below the level of the lower border of the tympanic membrane. It is pierced by a few small veins, which pass from the mucous membrane lining the cavity to join the internal jugular vein. Septic thrombosis of the latter may follow this course in otitis media. On the **Medial Wall**, which separates the tympanum from the internal ear, a slight elevation is present. It is produced by the first coil of the cochlea, and is termed the *promontory*. The fenestra of the cochlea (fenestra rotunda) is situated below and behind the promontory, and in life it is closed by a membrane which separates the tympanic cavity from the scala tympani of the cochlea. The fenestra of the vestibule (fenestra ovalis) is placed at a slightly higher level. It is closed by the base (foot-plate) of the stapes. The canal for the facial nerve produces a ridge, which passes backwards above the promontory and downwards behind it (Fig. 65). The **Lateral Wall** is formed mainly by the tympanic membrane (p. 213). In the upper and medial part of the **Posterior Wall** the epitympanic recess communicates with the tympanic (mastoid) antrum through a short passage, which is known as the *aditus*. The medial wall of the aditus is crossed by the descending part of the ridge produced by the facial nerve, and just above the ridge there is a slight prominence due to the lateral semicircular canal. It is through the

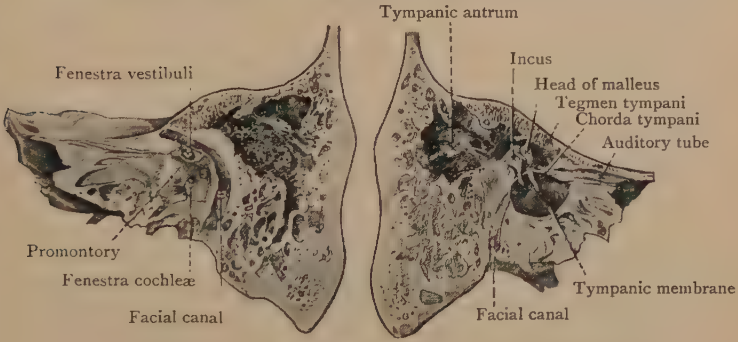


FIG. 65.—Section through a Left Temporal Bone along the line of the Tegmen Tympani.

aditus that infection reaches the tympanic antrum from the tympanic cavity.

The Auditory Ossicles.—The handle of the *malleus* is very intimately connected to the membrana tympani. Waves of sound impinging on the membrane thrust the malleus medially, and the movement is conveyed through it to the *incus* and *stapes*. Medial movements of the stapes set up a wave in the perilymph of the scala vestibuli, and this wave passes up the cochlea to the scala tympani. In the cochlea it stimulates the spiral organ of Corti, and it is dissipated below, where it impinges on the membrane which closes the fenestra of the cochlea (fenestra rotunda).

The **Tensor Tympani** occupies a small canal immediately above the auditory tube. Its tendon is inserted into the upper part of the handle of the malleus, and its contractions draw the bone medially, thus rendering the tympanic membrane tense. It is supplied by a branch from the otic ganglion, which lies on the lateral wall of the nasal pharynx, and obtains its motor fibres from the mandibular division of the trigeminal. The **Stapedius** emerges from a small opening in the posterior wall of the tympanic cavity, and is inserted into the neck of the stapes. It is supplied by the facial nerve just before it reaches the stylo-mastoid foramen. In paralysis of this nerve, proximal to the origin of the branch to the stapedius, the condition of *hyperacousis* occurs as a result of paralysis of the muscle.

The auditory ossicles and the tendons of their muscles are all covered by the mucous membrane, which extends backwards from the naso-pharynx along the auditory tube, through the tympanic cavity and aditus into the tympanic antrum and its furthest ramifications.

The **Tympanic (Mastoid) Antrum,** which is present at birth, is relatively larger in the child than in the adult. It lies behind and slightly above the tympanic cavity, with which it communicates through the aditus. Its lateral wall, formed by the squamous portion of the temporal, is only one-sixteenth of an inch thick at birth, but by the ninth year it has increased to nearly half an inch. The floor and medial wall, formed by the petrous portion of the temporal, separate the antrum from the posterior cranial fossa and the *descending portion of the transverse* (*lateral*) *sinus,* which forms a deep groove on the internal surface of the mastoid portion of the temporal bone. The aditus is placed above the level of the floor, and consequently can only act as an overflow when the antrum contains fluid. The roof is formed by a backward continuation of the tegmen tympani.

As the mastoid process develops at the end of the second year its diploë is gradually replaced by air-cells, which are derived from the antrum and maintain their connection with it, either directly or indirectly through neighbouring cells. Occasionally the process is entirely hollowed out by air-cells, the pneumatic type, or it may be practically solid, the sclerosed type. Various intermediate forms occur. The cells which lie in relation to the posterior wall of the external acoustic meatus are termed the "border cells," and when filled with pus they may rupture into the meatus and discharge through it.

Septic infection may spread from the tympanic antrum (1) directly, by necrosis of bone, (2) by venous thrombosis, or (3) by the lymph vessels.

Upward Spread of Infection, which may or may not be accompanied by destruction of the tegmen tympani, may cause an extra-dural abscess in the middle cranial fossa or an abscess in the temporal lobe of the brain. The veins which ascend through the petro-squamous suture open into the superior petrosal sinus, and through them the latter may become the site of a septic thrombosis. **Downward Spread** involves the internal jugular vein (p. 217).

By necrosis of the lower part of the medial wall of the antrum pus may pass **downwards and medially**, and reach the mastoid notch (digastric fossa)—Bezold's mastoiditis. It then passes downwards along the styloid process and the muscles attached to it, and gives rise to a deep-seated and dangerous form of cervical cellulitis. **Backward Spread** involves the transverse (lateral) sinus, and may pass along the cerebellar veins, producing a cerebellar abscess. **Forward Spread** infects the "border cells," and thence the pus may reach the external acoustic meatus, or may spread *laterally* and produce an abscess which points on the surface under cover of the auricle. When the pus reaches the outer surface of the bone it strips up the periosteum and forms a subperiosteal abscess. This accounts for the displacement of the auricle in a downward and forward direction. Abscesses in connection with the mastoid lymph glands (p. 112) lie superficial to the periosteum, and although they may displace the auricle forwards, they are never accompanied by downward displacement. Necrosis of the medial wall of the aditus exposes the facial nerve, and infection may pass along its sheath to the base of the brain, setting up a suppurative basal meningitis.

Tuberculous disease of the temporal bone, a common condition in children, may spread in any of the directions which have just been described. In this case, and also in chronic otitis media, the anterior auricular and the upper anterior group of the deep cervical lymph glands are usually enlarged.

The **Surgical Approach to the Tympanic Antrum** is made through a *curved incision*, which commences a quarter of an inch above the upper attachment of the auricle and extends downwards behind it on to the mastoid process. In the infant, prior to the development of the mastoid process, the facial nerve runs serious risks of injury if the incision is carried too far forwards, because its point of exit from the skull, the stylomastoid foramen, is situated on the infero-lateral aspect (p. 214). The incision is carried down to the bone, and the periosteum and soft structures of the flap are dissected forwards until the osseous part of the external acoustic meatus is visible, and the suprameatal spine and the posterior root of the zygomatic process of the temporal bone are recognised. If the posterior edge of the incision is elevated, an emissary vein is exposed emerging from the mastoid foramen, through which it communicates with the transverse sinus. When it is found thrombosed, the sinus will be similarly affected. Pus may sometimes be seen emerging from the mastoid foramen, and its presence indicates that pus will be found in the transverse sinus and is suggestive of a subdural abscess.

In chiselling through the bone to reach the antrum, care must be taken not to do so too high, lest the middle cranial fossa be opened, or too far posteriorly, lest the transverse (lateral) sinus be injured. The site selected lies below the posterior root of the zygomatic process and immediately behind the suprameatal spine. In the child, however, these bony prominences are not developed, and the bone lying just behind the postero-superior quadrant of the external acoustic meatus is the best guide (Stiles). The chisel is directed medially, downwards and forwards, *i.e.* parallel to the external acoustic meatus. It is advisable to bevel down the edges as the opening is deepened, and if the transverse sinus lies further forwards than normally, its bluish wall will be observed and can be protected. As a rule the sinus lies half an inch behind the external acoustic meatus, but its position is subject to variation (p. 228).

As soon as a cavity is reached, a probe is inserted and directed forwards in search of the aditus. The sensation produced as the probe slips into the passage is unmistakable, and if it is not experienced, the cavity, which is only an air-cell, is deepened until the antrum is opened. It may be necessary to remove the lateral wall of the aditus in order to throw the two cavities—tympanic cavity and antrum—into one. Before this is carried out, a Stacke's protector is passed into the aditus from the antrum, to preserve the facial nerve and the lateral semicircular canal (p. 217) from injury should the chisel accidentally slip during the operation. Occasionally, when the lateral wall of the aditus is being removed, the bone breaks away owing to the weakness caused by the facial canal (aqueduct of Fallopius), and a short piece of the facial nerve is exposed. This may be bruised during the remaining steps of the operation, or it may be pressed upon by the packing, etc., leading to a complete but transitory facial paralysis. Any irritation of the nerve sets up a spasm of the facial muscles, and the anæsthetist is able to warn the surgeon. When the antrum and tympanic cavity are syringed out, some of the fluid used may pass along the auditory tube into the nasal pharynx, and the anæsthetist must be prepared to prevent it from passing down into the larynx.

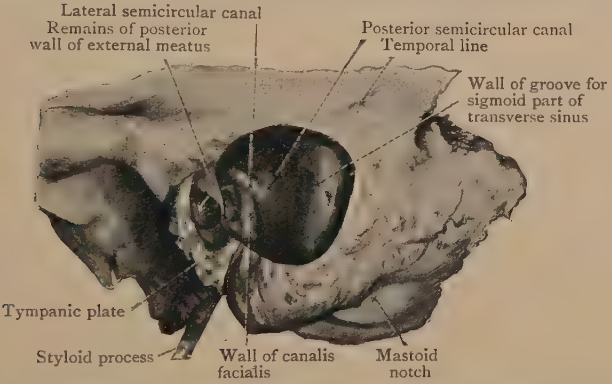

Lateral semicircular canal
Remains of posterior wall of external meatus
Posterior semicircular canal
Temporal line
Wall of groove for sigmoid part of transverse sinus
Tympanic plate
Styloid process
Wall of canalis facialis
Mastoid notch

FIG. 66.—Dissection of the Tympanic (Mastoid) Antrum and the petro-mastoid part of the Temporal Bone from the outer side. The arrow is passing through the aditus from the tympanic antrum into the tympanic cavity.

The mucous membrane of the tympanic cavity, together with the incus and malleus, may require to be removed; but the stapes, which is firmly attached to the fenestra of the vestibule (fenestra ovalis), is left *in situ*, as otherwise the internal ear would be opened.

After the antrum has been dealt with, the opening may be enlarged upwards and forwards to explore the middle cranial fossa (p. 234), or backwards to explore the transverse sinus and cerebellum (p. 220), if the symptoms point to a spread of the disease in either direction.

THE HEAD.

Bony Landmarks.—The *External Occipital Protuberance* lies just above a small depression, which indicates the upper end of the nuchal furrow when the head is held erect. Two inches above it in the median line the *Lambdoidal Suture* can be recognised as an irregular depression. The *Parietal Tuber* (*Eminence*), which overlies the supra-marginal convolution of the brain, can be felt on the side of the skull about two inches above the auricle. It is crossed by the *Superior Temporal Line* (*Crest*), which can be traced downwards and forwards to the zygomatic (external angular) process of the frontal bone, and downwards and backwards to a point a little above and behind the mastoid process. The *Asterion*, which corresponds to the articulation of the mastoid (postero-inferior) angle of the parietal bone with the temporal, forms a depression above and behind the external acoustic meatus. It lies about midway between the Sylvian point (p. 233) and the external occipital protuberance. Other bony landmarks have been dealt with on pp. 174, 175.

The **Skin of the Scalp** contains a large number of sebaceous glands, and is therefore a common site for sebaceous cysts or wens. These swellings are embedded in the superficial fascia, which in this region consists of a dense network of fibrous tissue containing very small lobules of fat. They can be moved with the scalp, and this feature distinguishes them from tumours in connection with the pericranium.

Numerous arteries supply the scalp, ramifying for the most part in the subcutaneous layer. They are derived from both the external and the internal carotid arteries, and ascend towards the vertex from the orbit, face, and neck. A free anastomosis occurs between the two groups of vessels and across the median line. In consequence, ligature of one external carotid fails to cure a cirsoid aneurism of the superficial temporal artery. Subcutaneous hæmorrhage is limited in amount owing to the density of the tissue, and for the same reason superficial septic infections remain localised and are extremely painful. When one of these vessels is cut the bleeding is plentiful, as its wall is held open and prevented from retracting by its attachment to the fibrous septa. At the same time the density of the subcutaneous tissue renders the cut vessels difficult to catch, but moderate pressure usually suffices to stop the hæmorrhage.

Owing to its rich blood-supply, the scalp possesses remarkable vitality. Large areas may be stripped up, and although they may only remain attached by narrow pedicles, if replaced they will heal with little loss from sloughing.

Vessels and Nerves of the Scalp.—The *Superficial Temporal Arteries* supply the lateral aspects of the scalp and ascend to the vertex to anastomose with one another. They divide into frontal (anterior) and parietal (posterior) branches, which communicate freely with the supra-orbital and frontal arteries in the forehead and with the posterior auricular and occipital arteries behind the auricle. The superficial temporal artery is accompanied by the *Auriculo-Temporal Nerve.*

The *Supra-Orbital* and *Frontal Arteries* accompany the *Supra-Orbital* and *Supra-Trochlear Nerves* (Fig. 59). They are branches of the ophthalmic artery, which arises from the internal carotid.

The *Posterior Auricular Artery* runs backwards and upwards from the external carotid, and lies superficial to the mastoid process. It supplies the auricle and adjoining area of the scalp, and is accompanied by the terminal branches of the *Great Auricular* (p. 110) and the *Lesser Occipital Nerves* (p. 110).

The *Occipital Artery* (p. 124) supplies the back of the scalp, and its branches accompany those of the *Greater Occipital Nerve* (p. 142).

The **Galea Aponeurotica (Epicranial Aponeurosis)** is a thin tendinous sheet which unites the frontal and occipital bellies of the epicranius (occipito-frontalis) to one another. Unless it is cut through in a transverse direction, scalp wounds do not tend to gape. Its lateral margins blend with the strong temporal fascia, and, together with the line of origin of the muscular bellies, completely shut in the subaponeurotic space which separates the galea aponeurotica from the pericranium. This space only contains some loose connective tissue and a few small arteries, but it is traversed by the important emissary veins which connect the intra-cranial venous sinuses and the superficial veins of the scalp. When pus collects in this region it can spread in all directions so as to elevate the scalp, which feels to the examining fingers as if it were lying on a water-bed. Incisions for the evacuation of such a collection are made near its lower border and parallel to the larger blood-vessels. The pus may destroy the pericranium and cause necrosis of the bones of the skull; and it may produce septic thrombosis of the *emissary veins*, and emboli may spread to the intra-cranial sinuses. On this account the subaponeurotic space is frequently referred to as the *Dangerous Area.*

The **Venous Return from the Scalp** may pass by (1) the extra-cranial or (2) the intra-cranial route.

1. The *extra-cranial route* is constituted by the veins corre-

sponding to the branches of the external carotid artery which are found in the scalp, and by the supra-orbital and frontal veins which unite to form the angular vein (p. 179).

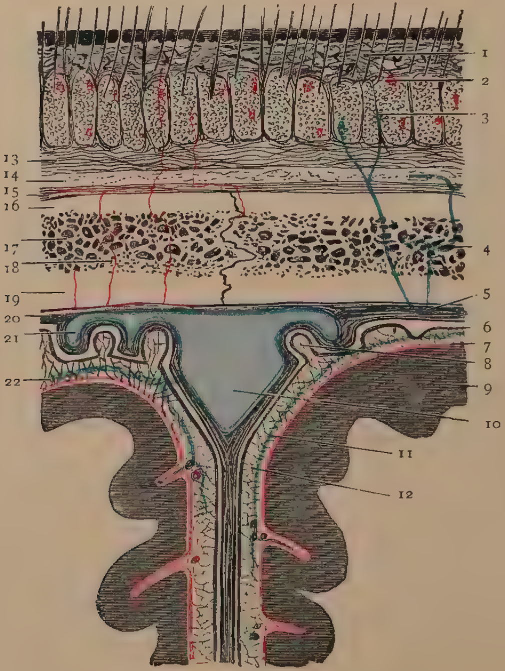


FIG. 67.—Diagrammatic Representation of a Frontal Section through the Scalp, Cranium, Meninges, and Cortex Cerebri (modified from Cunningham).

1. Integument.
2. Artery in superficial fascia.
3. Vein in superficial fascia.
4. Diploïc vein, connecting veins of scalp with veins of dura mater.
5. Vein in dura mater.
6. Arachnoid.
7. Pia mater.
8. Arachnoidal granulation.
9. Cortex cerebri.
10. Superior sagittal sinus.
11. Vein in pia mater.
12. Sub-arachnoid space.
13. Epicranial aponeurosis.
14. Lax connective tissue.
15. Pericranium.
16. Outer table of cranium.
17. Diploë.
18. Anastomosis between arteries of scalp and those of dura mater.
19. Inner table of cranium.
20. Dura mater.
21. Parasinoidal sinus.
22. Cerebral vein opening into superior sagittal sinus.

2. The venous blood may return along the *parietal emissary vein* into the superior sagittal (longitudinal) sinus, or along the *mastoid* and *condyloid emissary veins* into the *transverse* (*lateral*) *sinus*. Further, the supra-orbital veins communicate with

the ophthalmic veins, and by this route venous blood may be returned from the scalp to the cavernous sinus.

In addition to those mentioned above, emissary veins connect the superior sagittal (longitudinal) sinus with the veins of the nasal mucous membrane through the foramen cæcum, and the cavernous sinus with the pterygoid venous plexus. Epistaxis is common in children during a fit of violent temper or of crying, and it serves to reduce the intra-cranial blood-pressure. In this way the emissary veins may act as safety valves.

The **Pericranium** covers the outer surface of the skull and is easily stripped off except at the sutures, where it is connected with the endo-periosteal layer of the dura mater. The latter provides the bones of the skull with their blood-supply, and on this account removal of portions of the pericranium, in operations for tuberculous periostitis of the skull, is not necessarily followed by death of the exposed bone. A sub-pericranial hæmorrhage, or *cephal-hæmatoma*, is limited to the surface of some particular bone by the inter-sutural membrane. It is probably due to the rupture of some of the inter-sutural veins during the moulding of the fœtal head, and can easily be distinguished from the swelling produced by *Caput Succedaneum*, as the latter occurs in the scalp and is not limited to the surface of any particular bone.

The **Developing Cranium** expands rapidly to accommodate itself to the rapidly growing brain. At first it consists of a *membranous capsule*, but supporting cartilaginous bars soon appear in its base. The bars become ossified, and at the same time centres of ossification appear in the membrane to form the parietal bone and the squamous portions of the temporal, occipital, and frontal bones. In the regions of the *anterior* and *posterior fontanelles* the membrane is the only covering of the brain and its meninges at birth. The anterior fontanelle is placed at the area where, in the adult, the coronal and sagittal sutures meet, and through it the pulsations of the brain can readily be seen and felt. It should be closed by the end of the second year, but in rickets it is still widely open at that age. When the intra-cranial pressure is raised, *e.g.* in crying, the anterior fontanelle becomes tense, while it is sunken in conditions of malnutrition and exhaustion. Faulty development of the skull at the suture lines is accountable for the various forms of meningoceles (p. 541).

The cranial deformities produced by *hydrocephalus* (p. 230) are determined by the condition of the sutures at the time of the onset of the disease. If it occurs after the closure of the sagittal suture, the frontal and occipital regions are both affected, but if the lambdoidal suture is also closed the bulging is confined to the region of the forehead.

Fracture of the Skull.—In relation to cranial injuries hæmorrhage alone is of very little diagnostic value, but the accompanying or subsequent discharge of cerebro-spinal or subdural fluid is positive evidence of a fracture of the skull.

Anterior Fossa.—Fracture of the lamina cribrosa of the ethmoid bone is usually accompanied by laceration of the mucous membrane of the roof of the nose. This injury, therefore, gives rise to epistaxis, accompanied or followed by a discharge of cerebro-spinal fluid. In addition, there is frequently some loss of smell due to laceration of the olfactory nerves as they pass upwards from the nose. In fracture of the orbital part (plate) of the frontal bone, sub-conjunctival ecchymosis is a characteristic feature, and the hæmorrhage within the orbit may produce exophthalmos. When the frontal air sinus is also injured, blood may pass down the infundibulum to the middle meatus and be discharged from the nose. In these cases the hæmorrhage arises from the torn branches of the anterior division of the middle meningeal artery or, more rarely, from the ophthalmic vessels. Some of the blood may be swallowed, giving rise subsequently to hæmatemesis.

Middle Fossa.—This is the commonest site of fracture of the skull, partly because of its position but also because it is weakened by numerous canals and foramina. The tegmen tympani (p. 216) is usually fractured, and the tympanic membrane is torn. Blood and cerebro-spinal fluid are discharged from the external acoustic meatus, and the facial and auditory (seventh and eighth cerebral) nerves may be involved (p. 217). Sometimes the walls of the cavernous sinus are lacerated, and some of the nerves (third, fourth, and sixth cerebral) which lie in its lateral wall are paralysed (p. 229).

Posterior Fossa.—In this case the hæmorrhage does not become evident at once, unless the basilar part of the occipital bone is fractured, with laceration of the mucous membrane of the pharyngeal roof. Otherwise the blood is situated deeply at the back of the neck, and the discoloration does not become apparent for some days. It reaches the surface in the posterior triangle or in the neighbourhood of the mastoid process.

THE BRAIN AND ITS MENINGES.

The **Dura Mater** is a fibro-serous membrane. The *fibrous layer* forms the endo-periosteum of the skull, to which it is attached by numerous fibrous processes, but it is only strongly adherent over the floor of the cranial fossæ and along the suture lines. The meningeal vessels lie in the fibrous layer, and, owing to the ease with which the membrane may be stripped off from the bone, extra-dural blood-clots may attain a sufficiently large size to exert a fatal degree of intra-cranial pressure. The *serous layer* forms a covering for the brain and supports the thin endothelial walls of the cranial blood sinuses, which, consequently, do not collapse when they are wounded. The *falx cerebri* is a fold of the serous layer, which passes downwards in the middle line between the two cerebral hemispheres. Posteriorly, a similar fold, termed the *tentorium cerebelli,* projects inwards between the cerebellum and the cerebrum; and the two cerebellar hemispheres are partially separated by the *falx cerebelli,* a small fold which extends from the internal occipital protuberance to the posterior border of the foramen magnum.

The **Superior Sagittal (Longitudinal) Sinus** lies in the upper margin of the falx cerebri (Fig. 68). It begins at the foramen cæcum, where it communicates with the nasal veins (p. 225), and runs backwards to the internal occipital protuberance. At this point it communicates with the *straight sinus,* and turns laterally, usually to the right, to form the transverse sinus. It is half an inch in breadth posteriorly, and, therefore, trephine openings should not be made less than three-quarters of an inch from the median line. In addition to the parietal emissary vein (p. 224), it receives numerous cerebral veins, which run forwards and medially to enter the sinus. Backward movements of the head, which tend to empty the sinus, retard the outflow from the cerebral veins, owing to their forward inclination.

The **Inferior Sagittal Sinus** lies in the lower border of the falx cerebri, and is joined posteriorly by the *great cerebral vein* (*of Galen*) to form the **Straight Sinus,** which runs backwards on the upper surface of the tentorium cerebelli and in the base of the falx cerebri. At the internal occipital protuberance the straight sinus bends laterally to form the transverse sinus, usually of the left side, but at its termination it communicates freely with the superior sagittal sinus.

The **Transverse Sinus** runs laterally and slightly upwards from the internal occipital protuberance, grooving the occipital bone. Its highest point is placed on the mastoid (postero-inferior) angle of the parietal bone, and it then turns downwards, forming a deep groove on the mastoid portion of the temporal bone. Its horizontal part lies in the attached margin of the tentorium cerebelli (Fig. 68), but its vertical portion lies in the lateral wall of the posterior cranial fossa and is situated behind the tympanic (mastoid) antrum (p. 218). At its termination it runs medially and then forwards to reach the jugular foramen, through which it passes to become continuous with the internal jugular vein. It receives the mastoid emissary vein (p. 220) and tributaries from the cerebellum and the lower part of the lateral surface of the cerebrum.

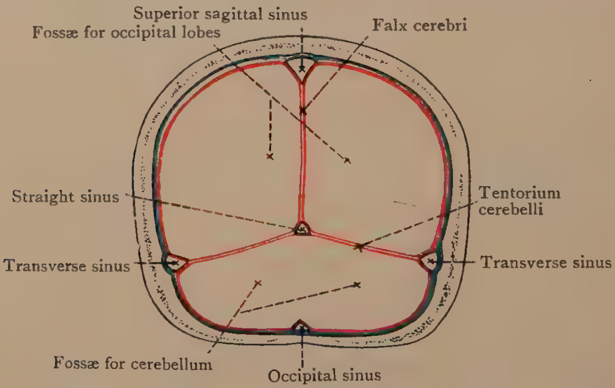


FIG. 68.—Oblique Section through Posterior part of Skull, showing the relationship of the Dura Mater to the Cerebral Sinuses. The fibrous layer of the dura mater is shown in blue, and the serous layer in red.

The transverse sinus corresponds roughly to the superior nuchal (curved) line on the occipital bone. In mapping it out on the surface it must be borne in mind that the sinus is about one-third of an inch wide. It commences a little above the external occipital protuberance and runs laterally to the asterion (p. 222). In this part of its course the sinus presents a varying degree of upward convexity, but the summit of its curve is rarely higher than a point one finger's breadth above the middle of the line joining the external occipital protuberance to the centre of the external acoustic (auditory) meatus. The descending part of the sinus runs downwards and slightly forwards to a point three-quarters of an inch below and behind the centre of the meatus. Very often, however, it approaches nearer to the meatus, and in this event it may be exposed during operations on the tympanic (mastoid) antrum.

The **Cavernous Sinuses** lie one on each side of the body of the sphenoid and are separated by the hypophysis (pituitary body), but they communicate freely with one another. Anteriorly, the cavernous sinus receives the *ophthalmic veins*, and posteriorly the blood is drained into the transverse sinus by the *superior petrosal*, and into the commencement of the internal jugular vein by the *inferior petrosal sinus*. The cavernous sinus communicates with the pterygoid venous plexus through the foramen ovale and the foramen of Vesalius. Between the endothelial wall of the sinus and the serous layer of the dura mater which supports it laterally, the third, fourth, and sixth cerebral nerves and the ophthalmic division of the fifth pass forwards to the orbit (p. 211), and a similar position is occupied by the internal carotid artery. Any or all of these structures may be involved by (1) tumours of the hypophysis (pituitary body) which extend in a lateral direction, (2) thrombosis of the sinus, (3) fractures of the skull in this region.

The **Occipital Sinus** (p. 231) lies in the attached border of the falx cerebelli, and runs upwards to join the right or left transverse sinus near its commencement.

The **Arachnoid** and the **Pia Mater** are two membranes which are applied to the surface of the brain more closely than the dura mater. The pia mater dips into all the fissures, but the arachnoid only does so in the case of the longitudinal fissure and the lateral fissure (of Sylvius). In certain areas the two membranes are separated by the subarachnoid cisterns. Of these the most important are situated on the basal surface of the brain, and in basal meningitis they become filled with purulent exudates, which may press on the neighbouring cerebral nerves (second to the eighth inclusive).

The Ventricular System of the Brain and Spinal Medulla.—The *central canal* is a small channel which extends upwards through the whole length of the spinal medulla into the medulla oblongata, where it expands to form the *fourth ventricle*. From the upper part of the fourth ventricle the *cerebral aqueduct* (*of Sylvius*) passes through the mid-brain to open into the *third ventricle*, which in its turn communicates with the *lateral ventricles* through the *inter-ventricular foramina of Monro.* The whole of this system is lined by ependyma, a thin membrane covered by ciliated columnar epithelium. The *cerebro-spinal fluid* fills the ventricular system, and normally drains away through certain apertures in the walls of the ventricles into the subarachnoid space. The largest of these apertures (the foramen of Magendie) is placed in the lower part of the roof of the fourth ventricle. The cerebro-spinal fluid is derived from the veins of the choroid plexus and circulates through the subarachnoid space, finally passing back into the venous system through innumerable microscopical arachnoidal villi which project into the intracranial blood sinuses. Some of these villi become enlarged pathologically and form the macroscopical Pacchionian granulations. The recognition of the circulation of the cerebro-spinal fluid made apparent the possibility of diminishing (or increasing) intracranial tension by intravenous injection of hypertonic (or hypotonic) solutions (Weed).

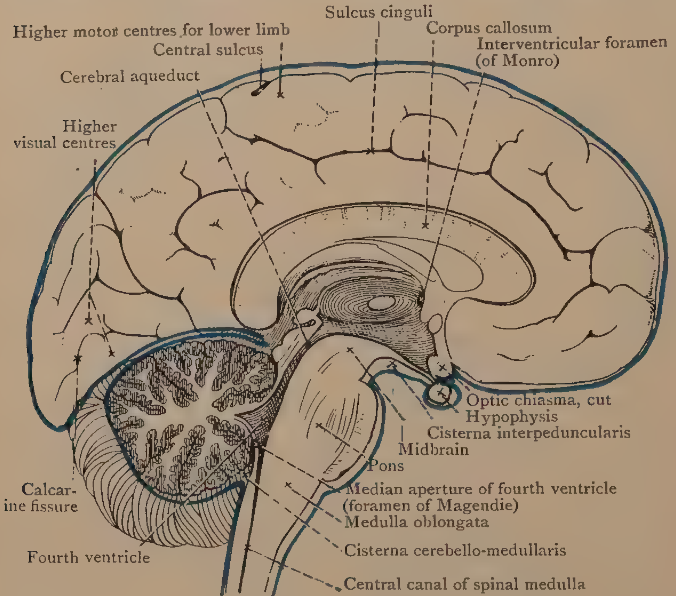

Sulcus cinguli
Higher motor centres for lower limb
Corpus callosum
Central sulcus
Interventricular foramen (of Monro)
Cerebral aqueduct
Higher visual centres
Optic chiasma, cut
Hypophysis
Cisterna interpeduncularis
Midbrain
Pons
Calcarine fissure
Median aperture of fourth ventricle (foramen of Magendie)
Medulla oblongata
Fourth ventricle
Cisterna cerebello-medullaris
Central canal of spinal medulla

FIG. 69.—Median Section through the Brain. The arachnoid is shown in blue.

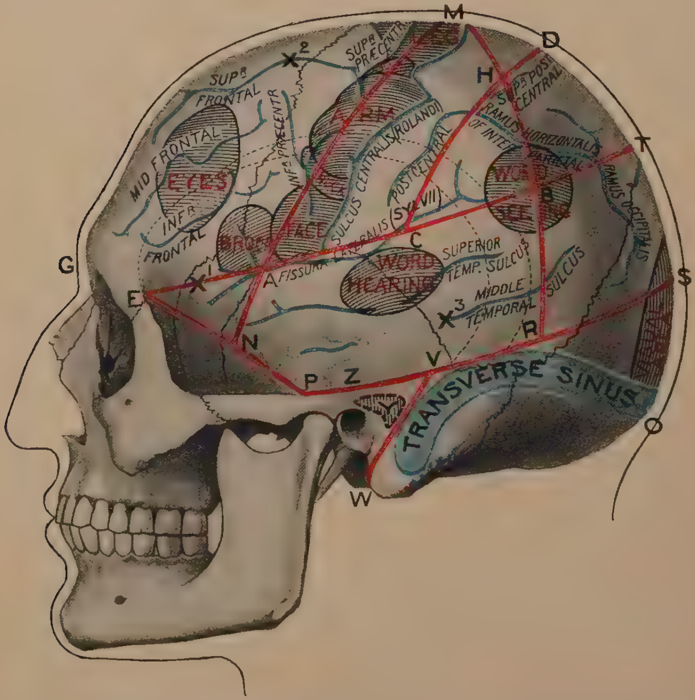
Congenital Hydrocephalus may be due (1) to occlusion of the arachnoidal villi by red blood corpuscles, which gain the subarachnoid space as the result of trauma during delivery, or (2) to an increase in the amount of the cerebro-spinal fluid secreted. On the ground of the latter theory, Stiles treats the condition by ligature of the common carotid arteries (p. 121).

Acquired Hydrocephalus may be caused by obstruction to the outflow into the subarachnoid space (p. 230) by adhesions following meningitis, or it may be produced by pressure on the great cerebral vein (of Galen). In the latter case the veins of the chorioid plexus become congested, and increased transudation takes place through the ependyma into the interior of the ventricles. In the former case the condition may be cured by making a fresh opening in the roof of the fourth ventricle so as to re-establish the communication between the ventricular system and the subarachnoid space. In this operation an anchor-shaped incision is employed. The curved base of the anchor lies along the superior nuchal (curved) lines of the occipital bone, and from its centre a vertical incision passes downwards along the ligamentum nuchæ. The knife is carried down to the bone and the two flaps are reflected downwards and laterally. The skull is opened below the level of the transverse sinus (p. 228) and at the thinnest part of the occipital bone, to one side of the median line. The opening is enlarged by removing the lower portion of the squamous part of the occipital bone piecemeal, including the posterior margin of the foramen magnum as far forwards as the posterior edges of the condyles. During the process considerable oozing occurs from injured diploic veins. The occipital sinus is ligatured above and below, and the dura mater is then opened along one side of the sinus. Horizontal incisions are made at each end of this cut, and two flaps of dura mater, one of which contains the ligated portion of the occipital sinus, are turned laterally. This step exposes the postero-inferior aspect of the cerebellum, covered by the arachnoid and the pia mater. The cerebellum is pressed upwards, away from the posterior aspect of the medulla oblongata (Fig. 69), and a large subarachnoid cistern (cerebello-medullary) is brought into view. After the cistern is opened, the lower part of the bulging roof of the fourth ventricle, which consists of ependyma and pia mater, is exposed, and the communication between the ventricular system and the subarachnoid space may be re-established.

The operation of *suboccipital decompression*, as practised by

Cushing, follows the same course as far as the incision of the dura mater.

In evacuating a cerebellar abscess the same route is adopted. After the membranes have been opened, a director is passed into the substance of the cerebellum at the point where the bulging is greatest. The instrument must not be passed in for more than 1½ inches, and it may be withdrawn and reinserted in different directions till the pus is found.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SUPR FRONTAL
MID FRONTAL
INFR FRONTAL
EYES
SUPR PRÆCENTR
INFR PRÆCENTR
ARM
LEG
FACE
BROCA
SULCUS CENTRALIS ROLANDI
POSTCENTRAL
SUPR POSTCENTRAL
RAMUS HORIZONTALIS OF INTERPARIETAL
RAMUS OCCIPITALIS
WORD SEEING
FISSURA LATERALIS (SYLVII)
WORD HEARING
SUPERIOR TEMP. SULCUS
MIDDLE TEMPORAL SULCUS
TRANSVERSE SINUS

FIG. 70.—Cranio-Cerebral Topography. The figure shows the positions of the motor and sensory areas and their relations to Chiene's lines.

G.	Glabella.
O.	External occipital protuberance.
M.	Mid-point between G and O.
T.	Mid-point between M and O.
S.	Mid-point between T and O.
E.	Zygomatic process of frontal.
P.	Pre-auricular point.
N.	Mid-point of EP.
R.	Mid-point of PS.
C.	Mid-point of AB.
CD	is drawn parallel to AM.
Z.	Post-auricular point.
VW.	Guide to anterior limit of transverse sinus.
Y.	Tympanic antrum.
X^1.	Site at which sub-arachnoid space may be opened.
X^2.	Site for draining lateral ventricle (Kocher).
X^3.	Site for draining lateral ventricle (Keen).

The Lateral Surface of the Cerebral Hemisphere.—The **Central Sulcus (of Rolando)** crosses this surface of the brain obliquely and separates the frontal from the parietal lobe. It begins at the supero-median border and runs downwards, forwards, and laterally to end a little above the posterior ramus of the lateral fissure (of Sylvius). The **Anterior** and **Posterior Central (Pre- and Post-Central) Gyri** are two parallel and nearly vertical convolutions, which lie one on each side of the central sulcus. The *motor area* is situated in the grey matter of the anterior central gyrus and in the anterior wall of the central sulcus (of Rolando), but it does not extend on to the surface of the posterior central gyrus. In front of the lower end of the sulcus, the higher centres controlling the movements of the face are situated, and above lie similar centres for the neck, upper limb, trunk, and lower limb, in that order. The last-named extends from the supero-median border on to the upper part of the medial surface of the hemisphere (Fig. 69).

The upper end of the central sulcus (of Rolando) corresponds to a point half an inch behind the mid-point of the line joining the glabella to the external occipital protuberance. The sulcus itself can be mapped out by drawing a line, inclined at an angle of 67½° to the sagittal suture, downwards and forwards from this point for 3½ inches. The direction of this line can be indicated on the head by placing the palm upon the scalp with the index-finger along the median line and the thumb extended so as to point just behind the apex of the chin. When the apex of the angle between the thumb and the index-finger corresponds to the commencement of the sulcus, the thumb itself indicates the situation of the sulcus on the surface. The motor area extends forwards for half an inch in front of this line. It is crossed by the superior temporal line at or near the lower part of the upper limb centre, and, therefore, that part of the skull which overlies the face centre is itself covered by the temporal muscle and fascia. In the child, owing to the smaller size of the muscle, the temporal lines lie entirely below the level of the motor area.

The **Lateral Fissure of Sylvius** breaks up into three rami as soon as it appears on the lateral surface of the brain. The point at which this takes place lies 1½ inches vertically above the mid-point of the zygomatic arch. It is known as the **Sylvian point** and is situated opposite the **Pterion,** the region where the great wing of the sphenoid articulates with the sphenoidal (antero-inferior) angle of the parietal bone. The *anterior horizontal* and *anterior ascending rami* extend on to the inferior frontal gyrus, and the convolutions which surround them are known as **Broca's Area.** This area is said to contain the motor speech centre, which is only developed on the left side of the brain. It lies immediately above the Sylvian point.

The **Posterior Ramus** of the lateral fissure of Sylvius runs backwards, forming the upper boundary of the temporal lobe ; and, posteriorly, it turns upwards into the parietal lobe. It may be mapped out on the surface by drawing a line from the Sylvian point backwards for three inches in the direction of the lambdoidal suture and then upwards for one inch. At its termination the ramus lies under cover of the parietal tuber (eminence), and is surrounded by the supra-marginal convolution. The *higher auditory centres* are placed in the superior temporal gyrus, below the middle part of the posterior ramus. Immediately behind the supra-marginal convolution lies the *angular* gyrus, in and around which there exists, on the left side, a widely represented *sensory speech centre*. It can be exposed by trephining the skull a little below and behind the parietal tuber.

The occipital lobe is covered by the upper part of the squamous portion of the occipital bone. It contains the higher visual centres, but they are situated chiefly on its medial surface.

The **Middle Meningeal Artery** (p. 185) enters the skull through the foramen spinosum, and runs laterally and slightly forwards over the floor of the middle cranial fossa between the dura mater and the bone. One finger's breadth above the mid-point of the zygomatic arch, it divides into anterior and posterior branches. The former runs upwards and crosses the deep surface of the pterion opposite the Sylvian point, and is then continued upwards along the anterior border of the motor area. The posterior branch runs backwards parallel to the posterior ramus of the lateral fissure of Sylvius and about three-quarters of an inch above the level of the zygomatic arch.

Surgical Approach to the Middle Cranial Fossa.—The middle cranial fossa is opened in operations in connection with the semilunar (Gasserian) ganglion, in ligature of the branches or main trunk of the middle meningeal artery, and in subtemporal decompression. The approach is very much the same in each case. The *incision* divides the skin and superficial fascia from the zygomatic (external angular) process of the frontal bone along the superior temporal line, and descends posteriorly to a point in front, above, or behind the auricle, as the case may be. In this way the upper branches of the facial nerve, which lie parallel to and a little below the base of the flap, are preserved intact, with the exception of the branch of supply to the frontalis muscle. The flap thus mapped out is turned downwards till the zygomatic arch is reached. The skull may be exposed by turning down a flap, consisting of the temporal fascia and muscle, or the fascia alone may be dissected downwards and the muscle may be split and each half retracted. (In Cushing's intermusculo-temporal method in ligature of the anterior division of the middle meningeal artery, a vertical incision is employed and is carried down, through the skin, fasciæ and muscle to the bone. In this way, damage to the nerve-supply of the frontalis is avoided and, if the temporal fascia be carefully sutured, a more satisfactory after-result is obtained.)

The point of application of the trephine varies with the individual operation. After a circular disc of bone has been removed the opening is enlarged by means of craniectomy forceps. The inner blade of this instrument is blunt, and formed so as to separate the dura mater from the inner surface of the skull while the bone is being removed.

(*a*) In **Ligature of the Anterior Division or of the Main Trunk of the Middle Meningeal Artery** the trephine is applied over the Sylvian point (p. 233), and, when the disc of bone is removed, the anterior division is exposed running upwards over the dura mater. Not infrequently the artery lies in a small canal on the deep surface of the bone, and in these cases a segment of the vessel will be removed along with the disc of bone. The opening must then be enlarged in a downward direction until the vessel is found leaving the canal, when its proximal end can be ligated.

(*b*) The operation of **Temporal Decompression** is undertaken to relieve the symptoms of headache and progressive loss of vision, which result from increased intra-cranial pressure due to cerebral tumours. The trephine is applied behind the Sylvian point in order to avoid the anterior branch of the middle meningeal artery. The opening is enlarged in a downward and backward direction till its diameter has been increased to from 2½ to 3 inches. While this enlargement is being carried out the posterior division of the middle meningeal artery is exposed. A crucial incision is made in the bulging dura mater after all the vessels which are likely to be cut have been secured.

(*c*) The approach to the **Semilunar (Gasserian) Ganglion** is described on p. 238.

(*d*) In order to evacuate an **Abscess of the Temporal Lobe** a trephine opening is made at a point two inches above the external acoustic meatus. The skin incision begins in front of the auricle, and is carried upwards and backwards above it and then downwards behind it. After the membranes have been opened. a director is passed medially into the brain at the point where it bulges most. If the abscess is not located the director is withdrawn, and then passed forwards and medially or backwards and medially until pus is found. Throughout the exploration the instrument should be kept parallel to the tegmen tympani, and it must not be inserted for more than 1½ inches lest the inferior (descending) horn of the lateral ventricle be entered. When Horsley's pus evacuator is used in place of a director, it must be passed in closed, and it should be opened at intervals of a quarter of an inch. In order to prevent severe laceration of the brain, the instrument must be kept closed while it is being inserted and withdrawn.

(*e*) In **Ligature of the Posterior Division of the Middle Meningeal Artery** the skull is trephined at a point one inch above and behind the external acoustic meatus. The skin incision is planned so as to give good exposure of the area.

The **Approach to the Anterior Cranial Fossa** may be made from in front or from the side. In the latter case the approach resembles that to the middle fossa, but the trephine is applied farther forwards and sufficiently high to preclude the possibility of opening through the lateral wall of the orbit.

The operation is generally performed for abscess of the frontal lobe, and it may be difficult to determine whether the right or left side is involved. On this account the anterior route may be preferred, as it enables the surgeon to expose the frontal bone on both sides of the median line. The *incision* extends from a little above the zygomatic (external angular) process of the frontal bone on one side to a corresponding point on the opposite side, and passes chiefly through the skin of the anterior dart of the scalp. In this way subsequent deformity due to scarring may be avoided, and a large flap may be turned downwards. The trephine must be applied 1½ inches above the superior margin of the orbit so as to avoid opening the frontal air sinus. The subsequent procedure is very similar to that described for the evacuation of an abscess in the temporal lobe.

During the *moulding of the fœtal head* at birth, the parietal bones may overlap one another to such an extent as to cause rupture of the superficial cerebral veins near their union with the superior sagittal sinus. The subdural hæmorrhage which ensues is usually localised to the motor centre for the lower limb (p. 233), and it gives rise to an irritative condition of the cortex and to symptoms of cerebral compression. Unless these signs are recognised and operation resorted to within ten days or a fortnight, irreparable damage may be done to the brain. Neglected cases of this kind give rise to one of the varieties of "birth palsy"—Little's disease. The hæmorrhage may be confined to one side only or it may be bilateral.

A curved incision, which is carried down to the bone, is made over the area and the flap is turned down. The thin superior border of the parietal bone is exposed and a blunt dissector is passed under it. An osseous flap, similar in shape to but slightly smaller than the flap of soft parts, is made with scissors and the bone is broken across its base. A similar flap of the dura mater is turned down, and the clot can then be removed.

The **Trigeminal or Fifth Cerebral Nerve** possesses a large (sensory) and a small (motor) root, both of which pierce the serous layer of the dura mater near the apex of the petrous portion of the temporal bone. The **Semilunar (Gasserian) Ganglion,** which is situated on the large (sensory) root as it lies on the petrous temporal, is enclosed in a recess of the serous layer of the dura mater, termed the *cavum Meckelii*. The *Ophthalmic*, *Maxillary*, and *Mandibular nerves* arise from the anterior border of the ganglion.

1. The **Ophthalmic Nerve** at once enters the lateral wall of the cavernous sinus (p. 229) and is conducted to the orbit (Fig. 63).

2. The **Maxillary Nerve** passes forwards to the foramen rotundum and enters the upper part of the pterygo-palatine (spheno-maxillary) fossa. Here it is connected to the spheno-palatine (Meckel's) ganglion, which distributes sensory nerves to the mucous membrane of the nose and palate. It then reaches the infra-orbital groove, in the floor of the orbit, and, after supplying the upper teeth, appears on the face as the infra-orbital nerve (p. 176).

As it lies in the pterygo-palatine fossa, the nerve may be reached by a needle passed medially from the surface. Advantage is taken of this fact in *tic douloureux* to destroy the nerve by injecting absolute alcohol or some other corrosive fluid into its sheath. The needle is inserted 4 cm. in front of the external acoustic meatus and immediately below the zygomatic arch. As the coronoid process of the mandible may obstruct the instrument or even break it, if the patient suddenly opens his mouth during the operation, it is better to keep the mouth open by means of a gag. The needle is then thrust medially through the masseter, temporal, and external pterygoid muscles to a depth of 5 cm. from the surface. If the point of the needle is not obstructed, as it may be by the lateral pterygoid lamina (external pterygoid plate) before it reaches this depth, it will have passed through the pterygo-maxillary fissure into the pterygo-palatine fossa. The contents of the syringe are injected at this point, and, even although they do not actually pass into the nerve sheath, the action of the destructive agent is sufficient to destroy the nerve and its branches.

3. The **Mandibular Nerve** (p. 186) runs forwards and laterally for a short distance from the semilunar ganglion and then passes downwards through the foramen ovale. At this point it is joined by the whole of the small (motor) root, which lies on the bone below the semilunar ganglion.

Removal of the Semilunar (Gasserian) Ganglion.—The approach in this operation and in ligature of the main trunk of the middle meningeal artery is similar to that described on p. 234, but a somewhat wider exposure is necessary. In order that this may be obtained, the temporal fascia is incised along the upper border of the zygomatic arch and the bone is divided at each end. When this is done the arch can be depressed for half an inch, and the temporal muscle is retracted into the interval between it and the skull. A trephine can now be applied a little above the level of the floor of the middle cranial fossa—which corresponds to the upper border of the undivided arch—and sufficiently far forwards to avoid the main trunk of the middle meningeal artery. In this region the thickness of the skull varies, being much greater below than above; and this difference must be borne in mind, as otherwise the blade of the trephine may tear through the dura mater above, before it has pierced the bone below. After the circular piece of bone has been removed, the trephine opening is enlarged and the middle meningeal artery is exposed and traced medially to the foramen spinosum, where it is ligated and divided. Before the ligature can be applied, the dura mater must be elevated from the floor of the fossa by blunt dissection, and, after the artery has been dealt with, this is continued until the lateral margin of the ganglion is reached. At this stage it is necessary to incise the wall of the cavum Meckelii (p. 237) in order to expose the ganglion. This step unavoidably opens the subdural space, and the fluid thus liberated increases the difficulty of the operation. The maxillary nerve is exposed running forwards to the foramen rotundum, and when it is traced backwards, the mandibular nerve is exposed a little in front of and medial to the ligated middle meningeal artery, and more posteriorly still the ganglion is reached. The ophthalmic nerve will be found in the antero-medial part of the cavum Meckelii as it pierces the lower part of the lateral wall of the cavernous sinus (p. 229). The large (sensory) root is exposed by stripping the serous layer of the dura mater backwards off the ganglion, and it is then divided. The maxillary and mandibular nerves are cut through as far away from their origin as possible, and the ganglion is then torn out along with the ophthalmic nerve. As the latter lies in contact with the thin endothelial wall of the cavernous sinus and is closely related to the internal carotid artery and the third, fourth, and sixth cerebral nerves (p. 229), few operators attempt to divide it with the knife. As soon as the ganglion is torn out severe hæmorrhage occurs, owing to the unavoidable laceration of the wall of the cavernous sinus, but it is readily controlled by pressure. It is seldom found possible to preserve the small (motor) root, and, following the operation, the muscles of mastication are paralysed on that side. In this condition the mandible is permanently twisted over to the side of the lesion by the unopposed action of the pterygoid muscles of the opposite side (p. 185). Another common *sequela* is thrombosis of the cavernous sinus with consequent proptosis, chemosis, and retinal hæmorrhage. Temporary blindness or permanent impairment of vision may result, and there is usually some temporary paralysis of the ocular muscles. The results of the alteration in the sensibility of the conjunctiva are described on p. 208.

Contents of the Posterior Cranial Fossa.—The **Medulla Oblongata** is the direct continuation of the spinal medulla, and is continuous above with the **Pons**. Ventrally, these two structures lie on the basilar portions of the occipital and sphenoid bones; dorsally, they are related to the cerebellum, which also overlaps them laterally. In the medulla oblongata and the pons the central canal of the spinal medulla expands to form the fourth ventricle, and the floor of this space contains the important respiratory and cardiac centres.

On each side the transverse fibres of the pons pass into the cerebellum as the brachium pontis (middle peduncle), and the region where the lower part of the brachium enters the cerebellum is known as the *cerebello-pontine angle*. In this region the facial and auditory nerves emerge at the lower border of the pons. At its upper extremity the pons becomes continuous with the mid-brain, which sinks into the basal surface of the cerebral hemispheres.

Tumours in the region of the cerebello-pontine angle usually involve the seventh and eighth cerebral nerves. They may be approached by the route described on p. 231 for the reopening of the foramen of Magendie. The operation is commonly performed in two stages, the first of which ceases after the complete removal of the lower part of the squamous portion of the occipital bone. In the second operation the occipital sinus is ligatured and divided along with the falx cerebelli (p. 229). The cerebellum is displaced to the opposite side, care being taken not to press it against the floor of the fourth ventricle, and access is thus obtained to the cerebello-pontine angle.

Lumbar Puncture in Intracranial Operations.—When it is desired to obtain a wide view of the surface of the brain, or to render its retraction less difficult, (*e.g.* in removing tumours of the hypophysis through the anterior cranial fossa), the object may be attained if, after the dura mater has been incised, lumbar puncture is performed and 20 to 30 ccs. of cerebro-spinal fluid are drawn off.

THE ABDOMEN AND PELVIS.

THE ABDOMINAL WALLS.

Surface Landmarks.—The *Costal Margins,* formed by the cartilages of the tenth, ninth, eighth, and seventh ribs (the last named being the lowest pair to reach the sternum), pass upwards and medially towards the sides of the xiphoid process and enclose between them the *Subcostal Angle.* The *xiphoid process* lies in the depression at the apex of this angle, and its pointed lower end is sometimes bent forwards, being then easily palpable beneath the skin.

The *Iliac Crest* forms the lower limit of the lateral aspect of the abdominal wall. It can be traced forwards to the *Anterior Superior Spine,* which lies on the same level as the second sacral vertebra. About 2 inches behind this point, a prominent *tubercle* can be felt on the outer lip of the crest ; it is utilised in mapping out the regions of the abdomen.

The fold of the groin extends downwards and medially from the anterior superior spine to the *tubercle* (*spine*) *of the pubis.* It overlies the *inguinal ligament* (*of Poupart*), which is slightly convex downwards owing to the traction exerted on it by the fascia lata of the thigh. This traction is transmitted by the ligament to the lateral abdominal muscles, which are attached to it, and renders them slightly tense when the thighs are extended. In the examination of the abdomen, it is advantageous that the muscles should be relaxed as far as possible, and to overcome the traction of the fascia lata, the patient's legs are drawn up, flexing both the hip and the knee-joints. This is the posture which is naturally assumed when there is much distension of the abdomen, since it allows the maximum amount of relaxation of the abdominal parietes.

The highest point on the iliac crest lies on a level with the lower part of the body of the fourth lumbar vertebra. In subjects with firm abdominal muscles, the umbilicus also corresponds to this level, but in obese subjects with lax abdominal parietes, it may sink down to a lower plane.

A linear furrow can be seen, in muscular subjects, in the middle line of the anterior abdominal wall. It corresponds to the *Linea Alba* (p. 251), a tendinous raphe which separates the two recti muscles. It widens out somewhat above the umbilicus, but below that level it is difficult to recognise. In multiparæ, however, and in children suffering from rickets, the two recti are often definitely separated below the umbilicus, so that the finger tips may be introduced between them.

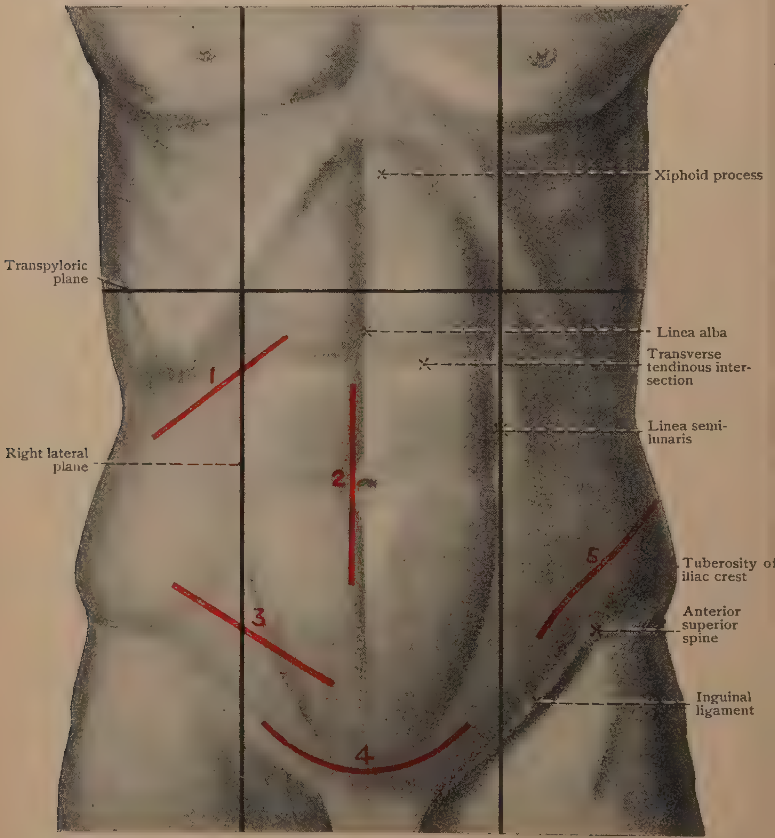
Xiphoid process
Transpyloric plane
Linea alba
Transverse tendinous intersection
1
Linea semilunaris
Right lateral plane
2
Tuberosity o
iliac crest
5
Anterior superior spine
3
Inguinal ligament
4

FIG. 71.—Surface Landmarks of the Anterior Abdominal Wall, showing the lines of some of the commoner incisions.

1. Cholecystotomy incision.
2. Intussusception incision.
3. Pelvic ureterotomy incision.
4. Supra-pubic cystotomy incision.
5. Lumbo-ilio-inguinal incision, lower part.

The lateral margin of the rectus muscle is indicated on the surface by a curved furrow—the *linea semilunaris*. It commences below at the pubic tubercle and passes midway between the umbilicus and the anterior superior iliac spine. It then runs upwards and slightly medially, crossing the costal margin near the tip of the ninth costal cartilage. Transverse furrows may sometimes be seen crossing the upper part of the rectus. They correspond to the lineæ transversæ (p. 250).

The *posterior superior iliac spine* may be found by tracing the iliac crest backwards. Its situation, when the body is erect, is marked by a dimple, which lies 1½ inches from the middle line. It is placed opposite the middle of the sacro-iliac joint and on a level with the second sacral spine.

The spines of the lumbar vertebræ lie at the bottom of the spinal furrow, but they are rendered visible when the trunk is flexed. On each side of the furrow is the prominence due to the *sacro-spinalis* (*erector spinæ*) *muscle*, the lateral margin of which can be felt, and sometimes seen, at a distance of 3½ inches from the middle line. The tip of the *twelfth rib* can be recognised as it emerges from under cover of this border. It lies about two inches above the midpoint of the iliac crest, but it must be remembered that the lowest palpable rib is not necessarily the twelfth, which is often rudimentary and completely hidden by the sacro-spinalis.

The **Subcutaneous Inguinal Ring** (**Ext. Abdom. Ring**), through which the spermatic cord leaves the inguinal canal, lies immediately above the pubic tubercle (spine) and may be examined by invaginating the skin of the scrotum from below. The anterior surface of the pubis is palpated, and the finger is carried upwards until the pubic crest is reached. It is then pressed *backwards* into the anterior abdominal wall, and can be felt to pass into a yielding gap, which possesses sharp and definite margins—the subcutaneous inguinal ring. If the finger is carried upwards, after reaching the upper border of the pubis, it can be moved about quite freely under the skin and fasciæ of the anterior abdominal wall.

To aid topographical description, the abdomen is subdivided into regions by two transverse and two vertical planes. (*a*) The **Subcostal Plane** passes horizontally through the body at the level of the most dependent parts of the tenth costal cartilages; it lies on a level with the upper part of the third lumbar vertebra. (*b*) The **Intertubercular Plane** passes horizontally through the tubercles of the iliac crests; it corresponds in level with the upper part of the fifth lumbar vertebra. (*c*) The **Right** and (*d*) the **Left Lateral Planes** are at right angles to the transverse planes, and each bisects the line joining the anterior superior iliac spine to the symphysis pubis.

In this way nine regions are mapped out on the surface. The three median areas are named, from above downwards, the *epigastric*, *umbilical*, and *hypogastric* regions; the six lateral areas are, the right and left *hypochondriac*, *lumbar*, and *iliac regions*, in that order from above downwards.

In addition to the above, the **Transpyloric Plane** is exceedingly useful. It is a transverse plane, which passes horizontally through the mid-point of the line joining the jugular (suprasternal) notch to the symphysis pubis, and it crosses the linea semilunaris at the costal margin (tip of the ninth costal cartilage). Posteriorly, it corresponds in level with the lower part of the body of the first lumbar vertebra.

The **Superficial Fascia** in the upper part of the anterior abdominal wall is directly continuous with the corresponding layer of the thoracic wall. Below it consists of (1) a superficial fatty stratum, known as *Camper's fascia*, which is continuous with the superficial fascia of the thigh, and (2) a deeper membranous layer, which is in direct contact with the aponeurosis of the external oblique muscle, no deep fascia intervening. The latter is known as *Scarpa's fascia*. It descends on each side in front of the inguinal ligament, and blends with the fascia lata of the thigh immediately below and nearly parallel to that structure. In the middle line it is carried down in front of the pubic bones and becomes continuous with the fascia of Colles, which invests the penis and scrotum, and forms the roof of the superficial perineal pouch (p. 380). In cases of extravasation of urine or of severe hæmorrhage into the pouch (p. 380), the lines of attachment of this fascia are accurately demonstrated.

Superficial Nerves.—The skin of the *anterior abdominal wall* is supplied by the anterior cutaneous branches of the *lower six thoracic* and *first lumbar nerves*. The tenth thoracic supplies the skin in the neighbourhood of the umbilicus. The ilio-hypogastric and ilio-inguinal nerves are both derived from L. 1; the latter reaches the surface at a lower level than the former, and supplies the skin over the tubercle (spine) of the pubis, the upper part of the scrotum, and the proximo-medial part of the thigh.

On the *lateral aspect* of the abdominal wall the skin is supplied by the lateral cutaneous branches of the seventh–eleventh thoracic nerves. Corresponding branches from the twelfth thoracic and ilio-hypogastric descend over the iliac crest to supply the skin of the gluteal region.

The anterior rami (ant. prim. divisions), which give off these various branches, descend obliquely as they pass round the abdominal wall. Their obliquity can be appreciated if the course of the eighth intercostal nerve is examined. Posteriorly, it is placed at the level of the inferior angle of the scapula, but anteriorly it ends midway between the xiphoid process and the

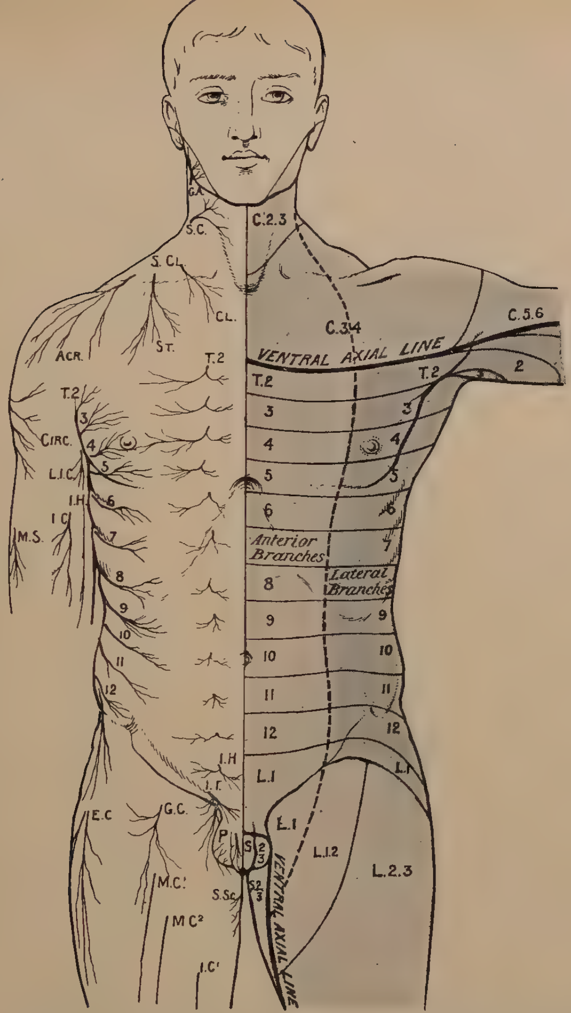
G.A
S.C.
S.CL.
CL.
ACR.
ST.
T.2
T.2
3
CIRC.
4
L.I.C
5
I.H
6
I C
M.S.
7
8
9
10
11
12
I.H
I.I
E.C
G.C.
P
S
2 3
M.C¹
S.Sc
S2 3
M C²
I.C'
C.2.3
C.3.4
C.5.6
VENTRAL AXIAL LINE
T.2
2
T.2
3
3
4
4
5
5
6
6
Anterior Branches
7
8
Lateral Branches
9
9
10
10
11
11
12
12
L.1
L.1
L.1
L.1.2
L.2.3
VENTRAL AXIAL LINE

FIG. 72.—The Nerve-Supply of the Skin on the Ventral Aspect of the Trunk. The whole of the area shown in the diagram is supplied by branches from the anterior rami (primary division) of the spinal nerves.

G.A, Great auricular nerve; S.C, N. cutaneus colli; S.CL, Supra-clavicular nerves; ACR, Posterior; ST, Middle; CL, anterior; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; CIRC. Cutaneous branch of axillary nerve; L.I.C, Medial cutaneous nerve of the arm (O.T. lesser internal cutaneous nerve); I.H, Intercosto-brachial; I.C, Medial cutaneous nerve of the forearm (O.T. internal cutaneous); M.S, Cutaneous branch of radial nerve; E.C, Lateral cutaneous nerves; G.C, Lumbo-inguinal nerve; M.C$^{1\ 2}$, Intermediate cutaneous nerves; I.C^{1}, Branch of medial cutaneous nerve; P, Branches of pudendal nerve; S.Sc, Branches of posterior cutaneous nerve of the thigh.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

umbilicus. The lateral cutaneous branches descend under cover of the fascia before they come to the surface, and so, despite the oblique course of the main trunks, the terminal branches supply areas of skin which are almost horizontal (Fig. 72).

The skin of the *posterior abdominal wall* is supplied by the *posterior rami* (*primary divisions*) *of the lower thoracic and upper lumbar nerves* (L. 1, 2, and 3) (Fig. 3).

These incline downwards in the fascia, and become cutaneous on the same horizontal plane as the lateral and anterior branches.

In **Herpes Zoster** the affected areas do not map out the course of a thoracic nerve, but the terminations of its cutaneous branches. They therefore form horizontal strips round the body, and they correspond exactly to the areas in which the "girdle pains" are experienced in locomotor ataxia. In the latter condition there is no reflex rigidity of the abdominal muscles, owing to interruption of the sensory portion of the reflex arc.

Referred Pain.—The anterior rami of the thoracic and of the first and second lumbar nerves are connected to the corresponding ganglia of the sympathetic by both white and grey rami communicantes (p. 127). The nerve-supply to the abdominal viscera is derived from the lower eight thoracic and the first lumbar segments and, consequently, afferent impulses from the viscera reach the same segments in the spinal medulla as do the afferent impulses from the skin of the abdominal wall. In pathological conditions the afferent impulses from the viscera may become so altered that they not only stimulate those cells for which they were originally intended, but also, by means of collaterals, they may stimulate neighbouring cells which are accustomed to receive impulses from the skin of the abdominal wall (Fig. 73). When the stimuli from these latter cells reach the brain, they are interpreted as painful sensations affecting the skin area supplied by the segment of the spinal medulla which is involved. Pain of this variety, which may be felt in a different region from the viscus at fault, is spoken of as *referred pain*, and the whole reflex is called the "viscero-sensory reflex" (Mackenzie). The areas in which referred pain may be felt in pathological conditions of the various viscera are dealt with under each individual organ (pp. 301, 316, etc.).

The **Superficial Veins** of the abdominal wall may be divided into an upper and a lower group. The *upper veins* join the internal mammary, intercostal, and lateral (long) thoracic veins, and so return their blood to the heart *via* the vena cava superior.

The *lower veins* join the femoral, and consequently drain into the vena cava inferior. These two groups communicate freely with one another through the *thoraco-epigastric vein*, which ascends from the groin to the region of the axilla. Owing to their position these veins are capable of considerable increase in size. In *obstruction of the vena cava inferior* this anastomosis provides a new channel for the return of blood from the lower limbs, and the thoraco-epigastric vein becomes specially enlarged. Further, the *para-umbilical vein* (*of Sappey*) passes from the left branch of the portal vein along the ligamentum teres to the umbilicus, where it communicates with both groups. Varicosity of the superficial abdominal veins may therefore occur in portal obstruction, but in this case the blood-flow in the distended veins is from the umbilicus both upwards and downwards, whereas in obstruction of the vena cava inferior the blood-flow is in an upward direction only.

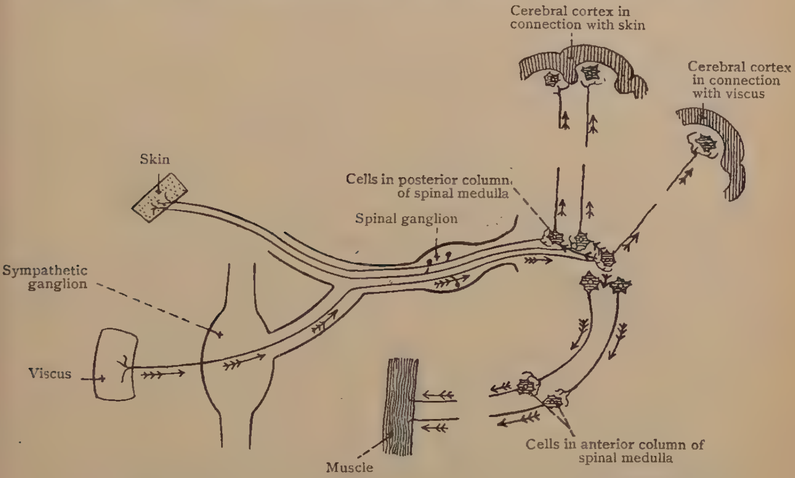
Cerebral cortex in connection with skin
Cerebral cortex in connection with viscus
Skin
Cells in posterior column of spinal medulla
Spinal ganglion
Sympathetic ganglion
Viscus
Muscle
Cells in anterior column of spinal medulla

FIG. 73.—Diagram to illustrate the Viscero-Sensory and Viscero-Motor Reflexes. The arrows indicate the passage of the afferent impulses from the viscus to the cortex, and show how they may overflow so as to stimulate the neighbouring cells in the spinal medulla.

The **Lymph Vessels** of the whole abdominal wall, below the level of the umbilicus, join the superficial sub-inguinal lymph glands (p. 405). Above the umbilicus, those from the anterior abdominal wall join the pectoral glands, while those from the posterior abdominal wall terminate in the subscapular group (p. 36).

Lymph vessels from the liver descend along the ligamentum teres to the umbilicus, where they establish communications with the lymphatics of the anterior abdominal wall. Cancer of the umbilicus may occur secondarily to cancer of the liver, and the infection may spread to the lymph-glands in the groin.

Lateral and Anterior Muscles of the Abdominal Wall.—The **external oblique** muscle arises from the lower eight ribs, and its fibres are mainly directed downwards, forwards, and medially. Above, it interdigitates with the serratus anterior (serr. magnus), and the deep fascia which covers both muscles forms a continuous sheet (p. 31). The lowermost (or posterior) fibres run vertically downwards, and are inserted into the anterior half of the iliac crest, so that between the last rib and the crest the external oblique has a *free posterior border*, which forms the lateral boundary of the lumbar triangle (of Petit). The remaining fibres become aponeurotic near the linea semilunaris, and pass in front of the rectus abdominis to reach the xiphoid process, linea alba, pubic symphysis, and crest. No muscular fibres are found below a line joining the anterior superior spine of the ilium to the umbilicus.

The lower border of the aponeurosis of the external oblique forms the *inguinal ligament* (*of Poupart*), which extends from the anterior superior spine to the pubic tubercle (spine). It is bent upwards and backwards on itself so that the upper surface of the ligament is grooved. The *lacunar ligament* (*of Gimbernat*) is the medial part of the folded-back margin of the inguinal ligament. It is attached to the pecten pubis (ilio-pectineal line) and possesses a free, crescentic, lateral margin, which is intimately related to the femoral (crural) ring (p. 408).

Just above the medial end of the inguinal ligament the spermatic cord pierces the aponeurosis of the external oblique, and the opening through which it passes is known as the *subcutaneous inguinal* (*ext. abdom.*) ring (pp. 243 and 258).

The **Internal Oblique** lies under cover of the preceding muscle. It arises from the lumbo-dorsal fascia (p. 273)—through which it gains attachment to the lumbar spines, so that it possesses no free posterior border—the iliac crest, and the lateral two-thirds of the inguinal ligament. The general direction of the fibres is upwards, forwards, and medially. The *uppermost fibres* are inserted into the lower ribs and their cartilages; the *intermediate fibres* form an aponeurosis, which is inserted into the linea alba; the *lowest fibres* arch over the spermatic cord and are inserted behind it as it leaves the inguinal canal. The latter blend with fibres of the transversus to form the *Falx Inguinalis Aponeurotica* (*Conjoined Tendon*).

The **Transversus Abdominis** is the deepest muscular layer

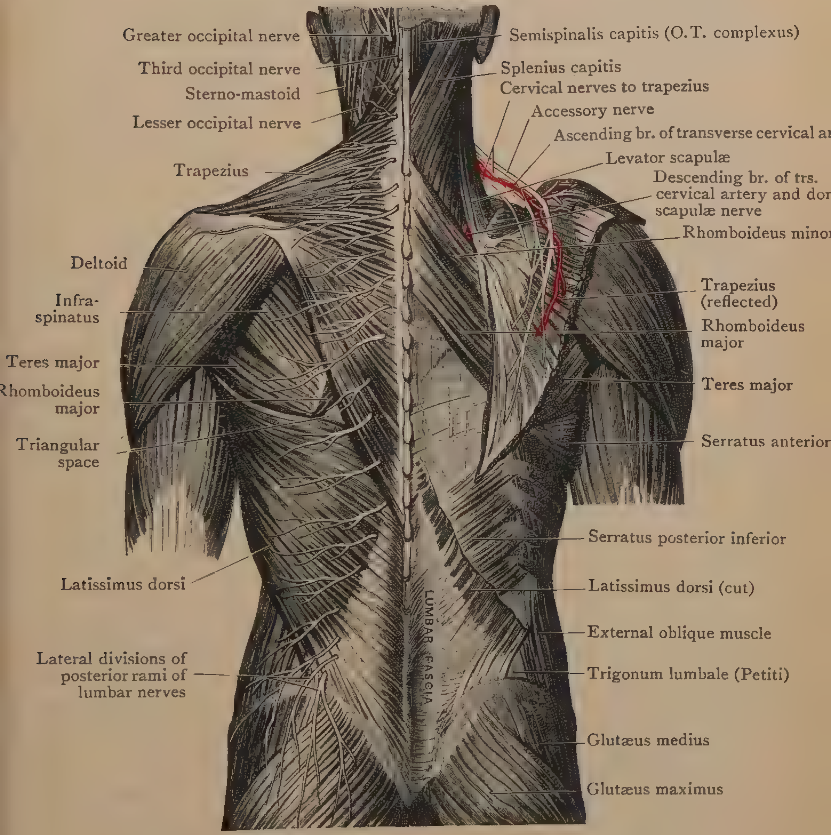
Greater occipital nerve
Third occipital nerve
Sterno-mastoid
Lesser occipital nerve
Trapezius
Deltoid
Infra-spinatus
Teres major
Rhomboideus major
Triangular space
Latissimus dorsi
Lateral divisions of posterior rami of lumbar nerves
LUMBAR FASCIA
Semispinalis capitis (O.T. complexus)
Splenius capitis
Cervical nerves to trapezius
Accessory nerve
Ascending br. of transverse cervical a
Levator scapulæ
Descending br. of trs. cervical artery and dor scapulæ nerve
Rhomboideus mino
Trapezius (reflected)
Rhomboideus major
Teres major
Serratus anterior
Serratus posterior inferior
Latissimus dorsi (cut)
External oblique muscle
Trigonum lumbale (Petiti)
Glutæus medius
Glutæus maximus

FIG. 74.—The Muscles on the Dorsal Aspect of the Trunk.

of the lateral abdominal wall. It arises (1) from the internal surfaces of the lower six costal cartilages, interdigitating with the diaphragm, so that the fascia on its deep surface (f. transversalis) is continuous with the layer on the under surface of the diaphragm; (2) from the lumbo-dorsal fascia; and (3) from the iliac crest and the lateral third of the inguinal ligament. The general direction of the fibres is horizontal, but the lowest fibres turn downwards to be inserted into the pecten pubis (ilio-pectineal line) where they take part in the formation of the falx inguinalis (conjoined tendon). The rest of the muscle forms an aponeurosis which gains attachment to the linea alba. *This aponeurosis is extremely narrow above,* but it gradually widens below.

The **Rectus Abdominis** muscle arises from the pubis and extends upwards in the interval between the linea alba and the linea semilunaris (p. 242). It is inserted into the anterior aspects of the fifth, sixth, and seventh costal cartilages. Irregular tendinous intersections cross the muscle, one at the umbilicus, a second at the xiphoid process, and a third midway between the other two. They are known as the *Lineæ Transversæ,* and are strongly adherent to the anterior wall of the rectus sheath.

The *sheath* of the rectus abdominis is a strong but incomplete aponeurotic envelope, which is formed by the aponeuroses of the three lateral abdominal muscles. It is differently constituted in its upper and lower parts.

(*a*) *Above the level of the midpoint between the umbilicus and the symphysis pubis.*—The aponeurosis of the internal oblique splits into an anterior and a posterior lamella at the lateral margin of the rectus. The anterior layer blends with the aponeurosis of the external oblique, and forms the anterior wall of the sheath, while the posterior layer blends with the aponeurosis of the transversus to form the posterior wall. Where the muscle rests on the costal cartilages near its insertion, the posterior wall of its sheath is deficient, as the internal oblique and transversus abdominis do not pass upwards beyond the seventh costal cartilage. In its upper part the posterior wall is not entirely aponeurotic, as, owing to the narrowness of its aponeurosis, the *upper fleshy fibres of the transversus* lie behind the rectus abdominis and almost reach the linea alba.

(*b*) *Below the level of the midpoint between the umbilicus and symphysis pubis.*—In this region the sheath of the rectus is formed anteriorly by the blended aponeuroses of the external oblique, internal oblique, and transversus. The posterior wall terminates in a free crescentic lower margin—the linea semicircularis (semilunar fold of Douglas)—at the level indicated above. This margin is usually fused with the underlying transversalis fascia, which is in direct contact with the rectus abdominis in the lower part of the abdominal wall.

Little difficulty is experienced in freeing the rectus abdominis from the posterior wall of the sheath, but the muscle is much more firmly adherent to the anterior wall, especially opposite the lineæ transversæ.

Tuberculous abscesses arising in the region of the costo-chondral junctions may track downwards, either lateral or medial to the linea semilunaris. In the former case they spread downwards between the internal oblique and the transverse muscles; in the latter case they pass into the sheath of the rectus and extend downwards behind the muscle.

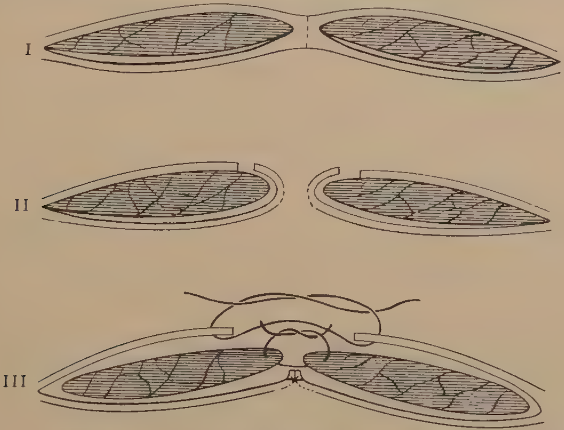

FIG. 75.—Diagram of Transverse Sections through the Rectus Abdominis Muscles, to illustrate the method of closing wounds in the supra-umbilical part of the linea alba.

I. The dotted line indicates the incision in the linea alba.

II. Prior to closure of the median wound, an incision has been made on each side into the anterior wall of the sheath.

III. Closure of the median wound. The deepest suture includes the cut edges of the parietal peritoneum as well as the sheath. The two recti and the anterior walls of their sheaths may be united by one continuous suture and not by two layers of sutures as shown in the figure.

Incisions in the Abdominal Wall.—Vertical Incisions through the linea alba have several advantages. (1) They are almost bloodless. (2) No muscle fibres are cut across. (3) No nerves are injured. (4) They give access to both sides of the abdomen.

When the linea alba and the subjacent fascia transversalis have been incised, the extra-peritoneal fat is exposed. This is a thin layer inferiorly, but it is much thicker above the umbilicus.

Owing to the close approximation of the recti below the umbilicus there is very little tendency for *ventral hernia* to occur after incisions through the lower part of the linea alba, but vertical incisions through the supra-umbilical part of this line tend to leave a weakness in the anterior abdominal wall when they heal. This is due to the normally existing interval between the upper portions of the two recti muscles, and may be prevented in the following way. A vertical incision, the length of the original wound, is made through the anterior wall of each rectus sheath along its medial border, and the medial edges of these cuts are stitched together (Fig. 75) by sutures which also pass through the peritoneum. In this way the gap is bridged by strong tissue which is not too tightly stretched. The medial edges of the recti and the anterior layers of their sheaths are stitched together over the newly formed deep layer of the abdominal wall (Stiles).

The same method may be adopted in the radical cure of a ventral hernia in this region.

The "**Gridiron Incision**" is planned so as to minimise, as far as possible, the subsequent weakness in the abdominal wall. The fibres of the various muscles are not cut across but are separated in the direction in which they run. It is most frequently employed in *inguinal colotomy* and in the *oblique approach to the vermiform process* (*appendix*) over M'Burney's point (which lies at the junction of the middle and lower thirds of the line joining the umbilicus to the anterior superior iliac spine).

The skin and fascia are divided downwards and medially, exposing the glistening aponeurosis of the external oblique, and in the upper part of the wound some of its muscular fibres. The aponeurosis is split in the line of the incision, *i.e.* parallel to the direction of the muscular fibres, and the split is continued upwards into the fleshy part of the muscle. When the cut edges are retracted, the lower part of the internal oblique is exposed. In this region the fibres of both the internal oblique and the transversus abdominis (transversalis) are practically horizontal, but in the lower part of the wound they turn downwards to form the falx inguinalis (conjoined tendon). These two parts of both muscles are separated from one another along a horizontal line at the level of the anterior superior spine. The fascia transversalis, which is now exposed, and the underlying peritoneum are opened at the same time, but great care must be exercised, as the bowel may be adherent to the latter.

If the muscular interval, obtained in this way, does not give sufficient access, the split may be extended both laterally and medially. In the former direction it may be carried to the anterior superior spine, exposing the *ascending branch of the* *deep circumflex iliac artery* (p. 257); in the latter, it is continued along the same horizontal line through the anterior wall of the rectus sheath. The muscle is retracted medially, and the posterior wall of the sheath is similarly divided, care being taken to avoid or to ligate the *inferior* (*deep*) *epigastric artery* (p. 257).

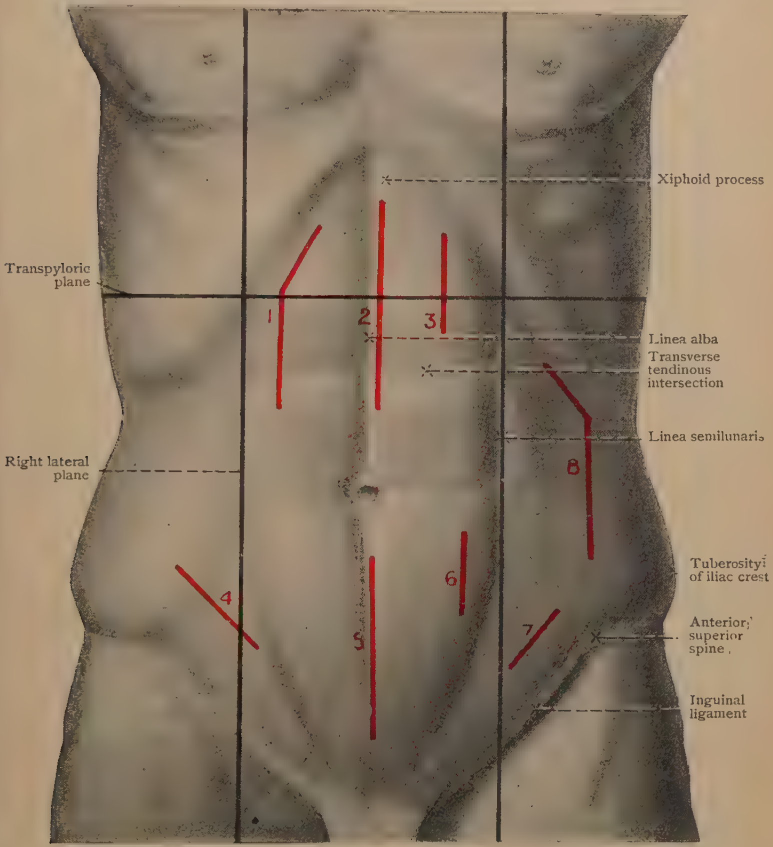
Xiphoid process
Transpyloric plane
Linea alba
Transverse tendinous intersection
Linea semilunaris
Right lateral plane
Tuberosity of iliac crest
Anterior superior spine
Inguinal ligament
1
2
3
4
5
6
7
8

FIG. 76.—Surface Landmarks of the Anterior Abdominal Wall, showing the lines of some of the commoner incisions.

1. Exposure of gall-bladder.
2. Supra-umbilical median incision.
3. Gastrostomy incision.
4. Gridiron incision.
5. Infra-umbilical median incision.
6. Colostomy incision (through rectus).
7. Colostomy incision.
8. Exposure of spleen and left colic flexure.

The abdomen may also be opened **through the rectus sheath.** In the *upper third,* this route gives access to the gall-bladder through the right rectus, and to the stomach through the left rectus. The direction of the incision may vary as it passes through the skin and fascia, but the anterior layer of the sheath and the muscle are split vertically, *i.e.* parallel to the muscular fibres, or the rectus may be freed and retracted. Finally, the posterior layer of the sheath and the muscular fibres of the transversus (p. 250) are divided, together with the subjacent and partially adherent fascia transversalis. This exposes the extra-peritoneal fat, which forms a layer of considerable thickness in this region. After it has been cut through, the parietal peritoneum becomes visible.

In the *lower third*, this route may be employed for appendicectomy. As soon as the rectus is split or retracted, the fascia transversalis is exposed, as the posterior wall of the sheath is deficient in this region (p. 250). The inferior (deep) epigastric artery, which lies on the fascia transversalis (p. 257), is also exposed, and it may either be retracted or ligated. The extra-peritoneal fat is very scanty, and may only be represented by a little areolar tissue.

Occasionally, *e.g.* for the removal of large tumours of the kidney or malignant growths of the colon, **it may be necessary to cut through the lateral abdominal muscles in a vertical direction**; *i.e.* across the muscular fibres. The incision commences above at the lower border of the tenth costal cartilage, and descends towards the anterior superior iliac spine. Below, it passes medially, above the inguinal ligament. It penetrates all the muscles of the abdominal wall along the same line and is limited, medially, by the inferior (deep) epigastric artery and the abdominal inguinal (int. abd.) ring.

The **Nerves of the Abdominal Wall** run in the interval between the internal oblique and the transversus abdominis—the upper, horizontally; the lower, downwards and medially. After they leave the costal margin, the seventh and eighth intercostal nerves run upwards and medially behind the rectus, while the ninth and tenth have a forward and downard inclination. The nerves of the abdominal wall include the *lower six thoracic nerves* and the *first lumbar nerve*, which is represented by two branches, the ilio-hypogastric and the ilio-inguinal. As they pass forwards they supply the lateral muscles of the abdominal wall, and at the linea semilunaris all, save the ilio-hypogastric and ilio-inguinal, enter the rectus sheath. Finally they supply the rectus muscle, and pierce it to become cutaneous (p. 244).

Their nerve-supply indicates that the muscles of the abdominal wall have arisen from the fusion of the muscles of six or seven adjoining segments, which were originally quite independent. In consequence of its segmental character the rectus abdominis may be cut across in operations and reunited with much less functional loss than results from section of muscles which have not arisen in this way (*e.g.* biceps brachii). In addition, one or more adjoining segments may become contracted, while the rest of the muscle is relaxed. Such localised areas of contraction may be due to cramp, but they are frequently found in connection with pathological conditions of the abdominal (p. 357) or even thoracic viscera. These cases are examples of the "viscero-motor reflex" (Mackenzie). The afferent impulses from the viscus at fault to the central nervous system not only set up the viscero-sensory reflex (p. 246) but they may also "overflow" into the motor cells of the anterior column (horn) of the grey matter. The efferent fibres of these cells supply the corresponding muscle segment, and in this way the localised contracted areas may be explained (Fig. 73).

In making incisions through the abdominal wall it is important that the position and course of the nerves should be borne in mind, for although one may be injured without any undesirable after-effects, the abdominal wall never completely recovers its muscular tone after section of the motor nerves. For this reason, when possible, the incisions are planned so as to avoid injuring the nerves, *e.g.* the median and gridiron incisions. In opening the abdomen through the rectus abdominis the muscle should, when possible, be retracted to the lateral side for the same reason.

A large **rectangular incision** is employed by Perthes in order to expose the region of the gall-bladder and the bile-duct. The vertical limb begins a little below the xiphoid process, and descends one finger's breadth to the right of the median plane, almost to the umbilicus. The horizontal limb passes to the right from the lower end of the vertical limb. The anterior wall of the rectus sheath is divided in the line of the vertical part of the incision, and the medial border of the muscle is defined. The finger can then be inserted behind the rectus so as to separate it from the posterior wall of its sheath.

Two transverse rows of sutures are passed through the anterior wall of the sheath and through the muscle, in the line of the horizontal part of the incision. When this has been done, the anterior wall of the sheath and the rectus may be cut across between the two rows of sutures, which serve to prevent retraction of the cut ends of the muscle. A large triangular musculocutaneous flap can then be turned upwards and to the right, until the terminal parts of the intercostal nerves are exposed as they pass forwards into the rectus. The posterior wall of the sheath, together with the underlying transversalis fascia and parietal peritoneum, is divided by an oblique incision, which is placed medial to the nerves and nearly parallel to the costal margin.

This method of approach, while providing good access to the region of the gall-bladder, produces little weakening of the abdominal wall, since none of the motor nerves are injured. In addition there is little danger of the occurrence of a post-operative hernia, as the anterior and posterior walls of the rectus sheath are not divided in the same line.

An incision, of varying length, **two inches below and parallel to the right costal margin**, gives good access to the gall-bladder. In obese subjects it may be necessary to prolong the lateral part of the incision in a downward direction. If, during this operation, the lower part of the patient's back is supported by a sand-bag, pillow, etc., the forward convexity of the lumbar region is increased, the viscera are pressed forwards, and the wound gapes so as to afford excellent access. Incisions planned to preserve the nerves, *i.e.* made at right angles to the costal margin, cannot be made to gape in the same way.

In all cases where the abdominal muscles are cut across the direction of their fibres, the wall must be sewn up in layers to diminish the subsequent weakness as far as possible.

The **Transversalis Fascia** covers the deep surface of the transversus muscle, and, inferiorly, it extends beyond the lower border of the muscle to reach the inguinal ligament. It extends medially behind the posterior wall of the rectus sheath, with which it partially blends. In the lower part of the anterior abdominal wall, where the rectus sheath is deficient posteriorly, the transversalis fascia lies in direct contact with the rectus abdominis. Above, it is continuous with the fascia on the under surface of the diaphragm, and below with the pelvic fascia. The connections of the transversalis fascia on the posterior abdominal wall are described on p. 275.

Arteries of the Anterior Abdominal Wall.—(*a*) Superficial.—The arteries which supply the lower part of the wall are all derived from the femoral, and ascend from the thigh. (1) The **Superficial Epigastric** crosses the middle of the inguinal ligament. (2) The **Superficial External Pudendal** runs medially across the spermatic cord. Both of these vessels are usually divided in the incisions for inguinal hernia. (3) The **Superficial Circumflex Iliac** supplies the skin in the neighbourhood of the anterior superior iliac spine.

(*b*) DEEP.—1. The **Inferior (Deep) Epigastric** artery arises from the external iliac, just above the inguinal ligament, and ascends in the direction of the umbilicus. At first it lies in the extra-peritoneal fat, but it soon pierces the fascia transversalis, and enters the rectus sheath by passing in front of the linea semicircularis (semilunar fold of Douglas). It then runs upwards on the deep surface of the rectus and anastomoses with the superior epigastric, which is descending from the internal mammary. A few small cutaneous branches pierce the linea alba and may be accompanied by protrusions of the extra-peritoneal fat.

The inferior epigastric artery may be injured if the oblique appendicular wound (p. 252) is increased downwards and medially, or when the rectus is split longitudinally.

The origin of the inferior epigastric lies half an inch above the inguinal ligament, and midway between the anterior superior iliac spine and the symphysis pubis. Its course may be indicated by a line drawn from its point of origin towards the umbilicus.

The important relations of this vessel to the inguinal canal and to the varieties of inguinal hernia are described on pp. 259 and 267.

2. The **Deep Circumflex Iliac** artery also arises from the external iliac, just above the inguinal ligament. It passes upwards and laterally along the inguinal ligament and the iliac crest. Just behind the anterior superior spine it gives off a moderately large branch, which ascends between the internal oblique and transversus, and may be injured when the gridiron appendicular incision is prolonged laterally.

The **Inguinal Region.**—The **Inguinal Canal** is an oblique cleft in the anterior abdominal wall above the medial half of the inguinal ligament. In the male it contains the spermatic cord, and this structure enters the canal at its upper end through the *Abdominal Inguinal* (*Int. Abd.*) *Ring*, which is situated in the fascia transversalis about half an inch above the inguinal ligament, midway between the anterior superior iliac spine and the pubic symphysis. The canal is about one and a half inches long, and extends downwards, forwards, and medially to the *Subcutaneous Inguinal* (*Ext. Abd.*) *Ring*, where the spermatic cord emerges from the abdominal wall. The subcutaneous inguinal ring is a triangular opening situated in the external oblique aponeurosis. Its base is formed by the lateral part of the pubic crest, and its apex is directed upwards and laterally. The upper (or medial) and lower (or lateral) margins of the opening, known as the *Crura* or *Pillars*, are formed by the external oblique aponeurosis.

The upper or deep end of the canal is therefore placed lateral to the lower or superficial end. This arrangement greatly diminishes the weakness produced in the anterior abdominal wall by the passage through it of the spermatic cord, for when the viscera are pressed against the abdominal inguinal (int. abd.) ring, *e.g.* in coughing, they are at the same time pressed against the posterior wall of the canal, which they force into apposition with its anterior wall. In this way the canal is practically closed.

The *Anterior Wall* of the inguinal canal is formed by the aponeurosis of the external oblique ; in addition, those fibres of the internal oblique which arise from the middle of the inguinal ligament assist in its formation in the lateral third of the canal.

In order to expose the spermatic cord as it lies in the inguinal canal, it is necessary to cut through the external oblique aponeurosis from the lower crus (pillar) of the subcutaneous inguinal ring for 1½ inches, parallel to the inguinal ligament. Medially, this incision exposes the cord, but laterally the cord is still covered by the lowest fibres of the internal oblique, and when they are divided the canal is laid open in its whole length.

The *Posterior Wall* of the inguinal canal is formed by the fascia transversalis ; medially, however, it is strengthened by the falx inguinalis (conjoined tendon), which lies in front of the transversalis fascia, but behind the cord (Fig. 77).

The lowest fibres of the transversus abdominis lie above the level of the lateral part of the canal, and in consequence its fleshy fibres take no part in the formation of the posterior wall. Its place is taken by the fascia transversalis, which descends beyond the lower border of the muscle to reach the inguinal ligament. The lower fibres of the internal oblique are placed, at their origin, in front of the spermatic cord, but as they pass medially they arch over it—forming the *Roof* of the canal—and then descend behind it in the falx inguinalis (conjoined tendon).

The weakest part of the posterior wall of the canal (the abdominal inguinal ring) is placed opposite the strongest part of the anterior wall; similarly, the weakest part of the anterior wall (the subcutaneous inguinal ring) is placed opposite the strongest part of the posterior wall (Fig. 77).

The *Floor* of the canal is formed by the upper surface of the inguinal ligament and, at its medial end, by the lacunar ligament (of Gimbernat).

The inferior (deep) epigastric artery arises from the external iliac as it lies in the extra-peritoneal fat below the abdominal inguinal (int. abd.) ring. At first the vessel lies below the ring, but it bends upwards and medially along its medial border. This relationship is of importance in connection with the operation for strangulated inguinal hernia, and is referred to again on p. 267.

Coverings of the Testis and Spermatic Cord.—In its descent (p. 261) from the abdomen to the scrotum, the testis traverses the inguinal canal. As it pushes its way through the transversalis fascia at the abdominal inguinal ring, it gains for itself and the spermatic cord a sheath of this fascia. This covering is known as the *internal spermatic* or *infundibuliform fascia.* The testis next passes under cover of the lower border of the internal oblique, and as it does so, it drags down some fibres of the muscle to form the cremaster. In the child, these fibres can be traced from the inguinal ligament and the lower border of the internal oblique down the anterior surface of the cord and up its posterior surface to the pubic tubercle (spine). Some extend to the testis, while others only pass downwards for a short distance on the cord before looping upwards again. This covering lies outside the internal spermatic fascia and is known as the *cremasteric muscle* and *fascia.* The contraction of the muscular fibres can draw the testis from the scrotum up to the subcutaneous inguinal ring.

On passing through the external oblique aponeurosis at the subcutaneous inguinal ring, the testis gains a third covering, the *external spermatic fascia.*

From the above it will be seen that the testis and that part of the spermatic cord which lies outside the inguinal canal have three coverings. In the medial part of the canal the spermatic cord has two coverings, and in the lateral part only one, the internal spermatic fascia.

The **Spermatic Cord** can be examined in the upper part of

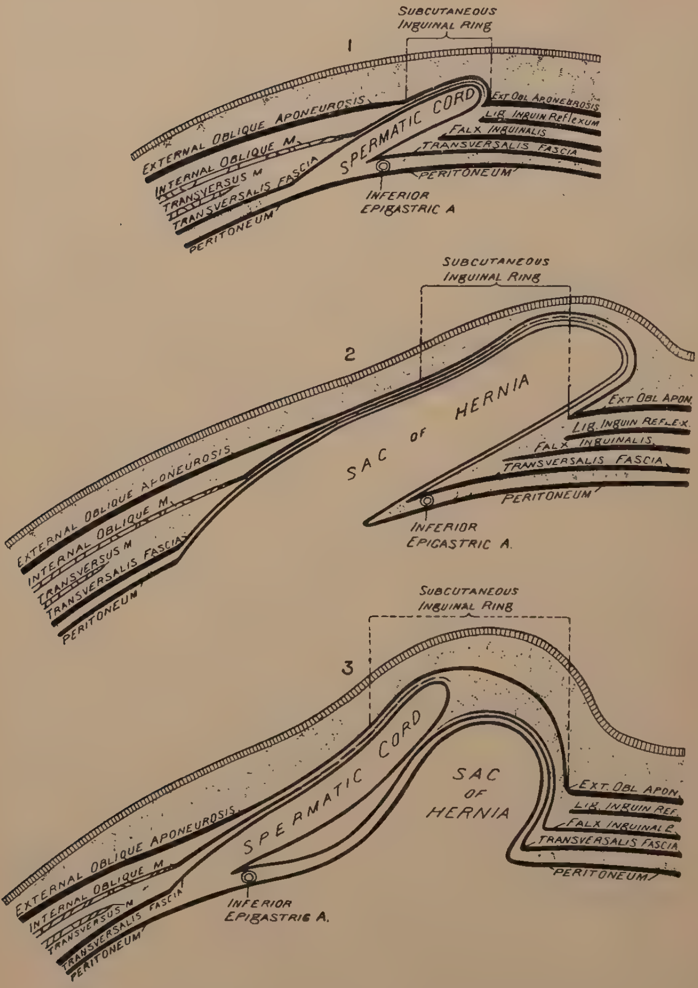
SUBCUTANEOUS INGUINAL RING
1
SPERMATIC CORD
EXT OBL APONEUROSIS
LIG. INGUIN REFLEXUM
FALX INGUINALIS
TRANSVERSALIS FASCIA
PERITONEUM
INFERIOR EPIGASTRIC A
EXTERNAL OBLIQUE APONEUROSIS
INTERNAL OBLIQUE M.
TRANSVERSUS M
TRANSVERSALIS FASCIA
PERITONEUM
SUBCUTANEOUS INGUINAL RING
2
SAC OF HERNIA
EXT OBL APON.
LIG. INGUIN REFLEX.
FALX INGUINALIS
TRANSVERSALIS FASCIA
PERITONEUM
INFERIOR EPIGASTRIC A.
EXTERNAL OBLIQUE APONEUROSIS
INTERNAL OBLIQUE M.
TRANSVERSUS M
TRANSVERSALIS FASCIA
PERITONEUM
SUBCUTANEOUS INGUINAL RING
3
SPERMATIC CORD
SAC OF HERNIA
EXT. OBL. APON.
LIG. INGUIN REF.
FALX INGUINALE
TRANSVERSALIS FASCIA
PERITONEUM
INFERIOR EPIGASTRIC A.
EXTERNAL OBLIQUE APONEUROSIS
INTERNAL OBLIQUE M
TRANSVERSUS M
TRANSVERSALIS FASCIA
PERITONEUM

FIG. 77.—Sections in the long axis of the Inguinal Canal.

1. The normal condition, showing the coverings of the spermatic cord.

2. Oblique inguinal hernia. Note the relation of the neck of the hernial sac to the inferior epigastric artery and observe that the sac descends within the coverings of the spermatic cord.

3. Direct inguinal hernia. Note the relation of the neck of the hernial sac to the inferior epigastric artery and observe that the external spermatic (intercolumnar) fascia is the only covering which it shares with the spermatic cord.

the scrotum, and as it lies in front of the pubis after leaving the subcutaneous inguinal ring. Surrounded by its coverings, it lies immediately beneath the skin and the two layers of superficial fascia (p. 244). The constituents of the cord—(1) the ductus (vas) deferens, (2) numerous blood-vessels, (3) lymphatics, and (4) nerves—are enclosed in the three coverings which have already been described.

(1) The *Ductus Deferens* lies posteriorly in the cord and is surrounded by the pampiniform plexus of veins. It possesses a small lumen and a very thick muscular wall, and consequently can easily be distinguished when the spermatic cord is examined. Its artery of supply, from the superior vesical, is closely applied to the duct.

(2) The *Pampiniform Plexus of Veins* ascends to the abdominal inguinal (int. abd.) ring, and there forms the spermatic vein. The *External Spermatic* (*Cremasteric*) *Artery* is derived from the inferior epigastric and is mainly distributed to the coverings. The *Internal Spermatic Artery*, a branch of the abdominal aorta, descends anteriorly in the cord and supplies the testis and epididymis.

(3) The *Lymphatics* ascend from the testis and join the lumbar or lateral aortic glands.

(4) The *External Spermatic Nerve* is a branch of the genito-femoral (genito-crural). It supplies the cremaster muscle and a sensory twig to the tunica vaginalis (Mackenzie). Numerous sympathetic nerves run down on the coat of the internal spermatic artery from the aortic plexus.

During attacks of *renal colic*, abnormal stimuli pass from the ureter by the sympathetic to the lower thoracic and upper lumbar segments. As a result, a viscero-sensory reflex is established. Pain is felt in the loin (p. 357) and shoots down to the testis (ext. spermatic nerve; L. 1 and 2), but does not affect the overlying skin of the scrotum (S. 2, 3, and 4). At the same time a viscero-motor reflex may be set up, and the resulting contraction of the cremaster muscle (ext. sperm. nerve) draws the testis up towards the subcutaneous inguinal ring.

Descent of the Testis.—At an early period of development the testis lies at the brim of the pelvis near the abdominal inguinal ring. It is attached to the lateral wall of the abdomen by a mesentery, the *mesorchium*, and is connected by the *gubernaculum* to the integument which forms the lowest part of the scrotum. This cord consists of condensed mesoderm, and later contains numerous unstriped muscle fibres. It is present when the anterior abdominal wall is being formed, and the muscles have to accommodate themselves so as to enclose it in the inguinal canal. At the same time the umbilical arteries, which lie medial to the testis, lift up a peritoneal fold so that the gland projects into a small peritoneal fossa. Until the seventh month this fossa lies opposite the abdominal inguinal ring, but during the eighth month it invades the inguinal canal.

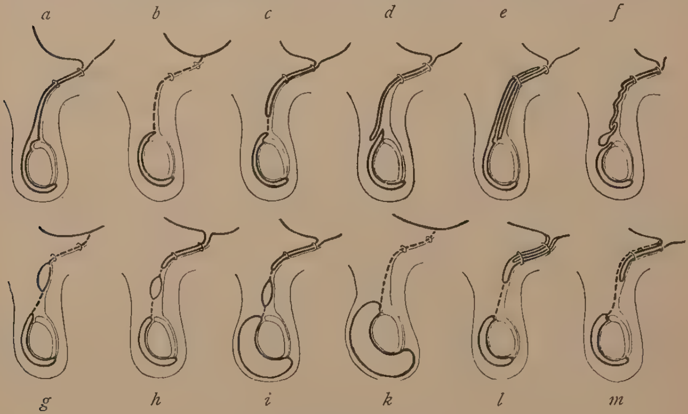

FIG. 78.—Diagrams to illustrate the Different Conditions of the Processus Vaginalis.

a. Fœtal condition, showing completely patent processus vaginalis.
b. Normal condition, with obliterated processus vaginalis and patent tunica vaginalis testis.
c, *d.* The processus is only partially obliterated.
e. The closure of the processus has been oblique.
f. The funicular part of the process is shut off from the tunica vaginalis and repeated attempts at obliteration have led to the valve-like constrictions.
g. Encysted hydrocele of the spermatic cord.
h. As *g*, but the proximal part of the processus is patent.
i. As *h*, but a hydrocele is present in the tunica vaginalis.
k. Hydrocele of the tunica vaginalis.
l. One variety of encysted hernia, in which the closed abdominal end of the processus vaginalis has been invaginated within the partially patent funicular part of the processus.
m. As *b*, with, in addition, the sac of an acquired inguinal hernia.

At the same time it becomes elongated and forms the *processus vaginalis*. Thereafter the testis enters the inguinal canal, and it gains its permanent scrotal position during the ninth month. The part of the processus which is related to the spermatic cord loses its connection with the general peritoneal cavity and becomes converted into a solid cord. The lower part of the processus remains patent and constitutes the tunica vaginalis (p. 269).

Congenital Anomalies.—In **Ectopia Testis** the gubernaculum has failed to acquire its connection with the bottom of the scrotum, but instead has become attached to the skin of the region in which the testis is found. It may lie in the perineum, in the groin, or near the anterior superior iliac spine, but it always maintains its normal relation to the processus vaginalis, which is also misplaced.

Congenital Inguinal Hernia; Congenital Hydrocele.—Numerous developmental errors may occur in connection with the closure of the processus vaginalis. All the congenital varieties of inguinal hernia and of hydrocele result from such errors. In Fig. 78 (*b*) the normal condition is depicted. The processus remains patent below as the tunica vaginalis testis, but above it is represented by a fibrous cord. In (*a*) the processus remains patent throughout, *i.e.* a persistence of the fœtal condition. If the opening at the neck is sufficiently wide, bowel or omentum will enter the sac and pass down to its lower end. It will then be in close contact with the testis and only separated from it by the visceral layer of the patent tunica vaginalis (*vaginal type of oblique inguinal hernia*). If the opening at the neck is too small to permit the passage of a hernia, serous fluid from the peritoneal cavity may find its way into the sac and give rise to an *Intermittent Hydrocele.* The condition is not always present, as when the child lies down the fluid passes back into the general peritoneal cavity. Owing to this intermittent character, it may be mistaken for a hernia. Further, it may be confused with a hydrocele of the cord or of the tunica vaginalis, because it cannot be reduced by taxis.

In (*c*) the tunica vaginalis has been shut off, but the proximal part of the processus remains patent and maintains its connection with the general peritoneal cavity. This condition gives rise to the *Funicular Type of Oblique Inguinal Hernia,* which constitutes 95 per cent (Stiles) of all congenital herniæ. If the neck is not large enough to admit a hernia, an intermittent hydrocele of the funicular type may occur. The conditions shown in (*d*) and (*e*) are very similar. The tunica vaginalis is closed above, and the proximal part of the processus remains patent. In both, but more especially in (*e*), the line of closure has been oblique and not horizontal as in (*c*). In order to open the sac of a hernia of the funicular type affecting (*e*), three layers of peritoneum must be incised. This variety was formerly explained as an acquired hernia descending behind a partially closed processus vaginalis.

The processus may be shut off from the tunica vaginalis below, and from the general peritoneal cavity above, but yet remain patent in its intermediate part (*g*). Should this sac become distended with serous fluid, it will form an *Encysted Hydrocele of the Cord*. A similar variety is shown in (*h*). The processus has been obliterated in two areas, but the patent portions are so arranged that the occurrence of a funicular hernia, an encysted hydrocele of the cord, and a hydrocele of the tunica vaginalis testis at one and the same time is quite possible (*i*). In (*l*) an acquired hernia is shown invaginating an encysted hydrocele, a condition which can only occur when there is little fluid in the hydrocele; in (*m*) it is seen passing down posteriorly.

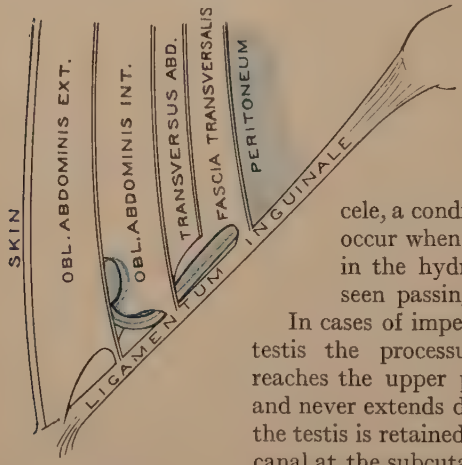

FIG. 79.—Diagram of Inguinal Canal to show the Position of an Interparietal Interstitial Hernia. Portions of the different layers of the abdominal wall have been removed. The patent processus vaginalis and the peritoneum are shown in blue.

In cases of imperfect descent of the testis the processus vaginalis rarely reaches the upper part of the scrotum and never extends down into it. When the testis is retained within the inguinal canal at the subcutaneous inguinal ring, the processus is nearly always patent, and should bowel or omentum descend into it, the commonest type (interparietal) of *interstitial hernia* is produced (Fig. 79). The neck of the sac lies at the abdominal inguinal ring, and its fundus lies between the external oblique aponeurosis and the internal oblique muscle. The hernia may enlarge in the region of the abdominal inguinal ring and give rise to a dilatation of the sac, just beyond its neck. This enlargement lies between the fascia transversalis and the peritoneum, and is known as a *pro-peritoneal hernia*. In this case it is associated with the interstitial interparietal form. The whole hernia is dumb-bell shaped, the constriction being placed at the abdominal inguinal (int. abd.) ring.

If the testis with its patent processus emerges from the inguinal canal but fails to descend into the scrotum, a *superficial inguinal hernia* may result. In these cases the sac is often bilocular, the one enlargement being situated under the skin and the other in the inguinal canal. Occasionally the sac of an inguinal hernia not only extends into the scrotum but possesses a second loculus either just outside or within the inguinal canal.

An **Acquired Oblique Hernia** enters the inguinal canal at the abdominal inguinal ring and makes its way down into the scrotum inside the spermatic cord (Fig. 77). The constituents of the cord are spread out over the surface of the sac and the ductus deferens is always found on its posterior aspect.

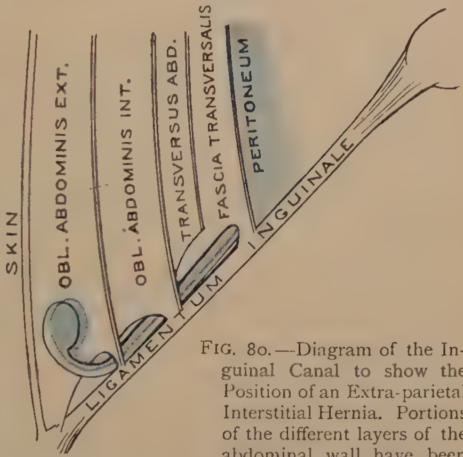

FIG. 80.—Diagram of the Inguinal Canal to show the Position of an Extra-parietal Interstitial Hernia. Portions of the different layers of the abdominal wall have been removed. The patent processus vaginalis and the peritoneum are shown in blue.

Inguinal Hernia: Radical Cure.—The *Incision* for inguinal hernia is made along the medial half or two-thirds of the line joining the anterior superior iliac spine to the root of the penis, and should expose, in its lateral part, the aponeurosis of the external oblique. The fasciæ of Camper and Scarpa (p. 244) and the superficial epigastric and external pudic arteries, which lie between them, are divided. At the medial part of the wound the spermatic cord is exposed and the surgeon can at once define the subcutaneous inguinal ring. The cord is freed and lifted up to the surface, dragging the testis upwards in the scrotum. In order to avoid injuring the ductus deferens, forceps are carefully applied to the margins of the cord, which is put on the stretch downwards and medially (Stiles). The external spermatic fascia (p. 259) is very thin, and the muscular fibres of the cremaster, which are very well marked in the male infant, are visible through it. These two layers are carefully stripped off after they have been divided in the long axis of the cord. The veins of the pampiniform plexus and the internal spermatic artery can now be seen on the anterior surface of the sac, but before they can be separated from it, the internal spermatic (infundibuliform) fascia (p. 259) must be incised and stripped off. If this is not done, difficulty will be experienced in separating the vessels without injuring them. At the same time the remaining veins and the ductus deferens should be freed from the posterior aspect of the sac. The neck of the sac is carefully isolated, ligated, and divided. It may be allowed to retract into the abdomen or may be transplanted up the canal towards the anterior superior iliac spine. The rest of the sac is removed, but, if it is of the vaginal type (Fig. 78 (*a*)), the lower part may be stitched up to form a closed tunica vaginalis testis.

The same approach and method of dividing the coverings of the cord are employed in such conditions as *varicocele* (p. 268), *hydrocele of the cord*, and *hydrocele of the tunica vaginalis*.

In infants or young people where the hernia is due to the presence of a preformed sac and not to any inherent weakness of the abdominal wall, the condition may be completely cured by the removal of the sac, but it is sometimes advisable to insert one or two stitches to narrow the subcutaneous inguinal ring or to approximate the falx inguinalis (conjoined tendon) to the inguinal ligament.

In elderly patients it is necessary to strengthen the weak area in the abdominal wall which has predisposed them to hernia. The external oblique aponeurosis is split up along the course of the canal and the lower borders of the internal oblique and the falx inguinalis are defined. A few mattress sutures may now be passed through the deep surface of the thickened lower portion of the external oblique aponeurosis, which is forming the inguinal ligament, and up through the falx inguinalis so as to drag the latter structure downwards behind the former. The close relationship of the femoral vessels to the inguinal ligament must be borne in mind when these sutures are inserted. In this way the posterior wall of the inguinal canal is greatly strengthened. A similar effect can be produced in the anterior wall by uniting the two portions of the external oblique in such a way that they overlap.

When sutures are being passed through the posterior wall of the canal in the neighbourhood of the abdominal inguinal (int. abd.) ring, the inferior epigastric vessels must be carefully avoided. In all cases where the canal is artificially narrowed, the surgeon must guard against closing it too tightly lest undue pressure be exerted on the spermatic cord.

Oblique inguinal hernia of long duration and great size tends to take a more and more direct course through the abdominal wall. The neck of the hernia gradually enlarges the abdominal inguinal ring downwards and medially, until it comes to lie directly behind the subcutaneous inguinal ring. In these cases, after the hernia has been reduced, the examining finger can be passed directly backwards through the abdominal wall into the abdomen. This alteration in the direction of the inguinal canal is necessarily accompanied by an alteration in the direction taken by the inferior epigastric artery. It now passes medially to the pubic tubercle (spine) and then ascends behind the lateral border of the rectus abdominis.

Direct Inguinal Hernia.—In the lower part of the anterior abdominal wall the *Triangle of Hesselbach* can be identified. Its base is formed by the medial end of the inguinal ligament, its medial side by the lateral border of the rectus abdominis, and its lateral side by the inferior epigastric artery, which separates the triangle from the abdominal inguinal ring. Occasionally, hernia occurs through the fascia transversalis in the floor of Hesselbach's triangle. This variety, known as a *Direct* (*or Internal*) *Hernia*, enters the inguinal canal at its medial end and immediately opposite the subcutaneous inguinal (ext. abd.) ring. In doing so, it usually passes directly through the falx inguinalis (conjoined tendon), though it may appear at its lateral margin. Its subsequent course is the same as that of an oblique hernia. The most important difference between these two varieties (the direct and the oblique) lies in their relationship to the inferior epigastric artery. The neck of the sac of an oblique hernia is placed **lateral** to the artery, while the neck of the sac of a direct hernia is **medial** to the vessel (Fig. 77).

In a case of *old-standing inguinal hernia* some difficulty may be experienced in deciding which of the two varieties is present, as in both cases the hernial opening is large and the exploring finger will pass directly through the abdominal wall. Should such a hernia become strangulated, the surgeon will be well advised to incise the constricting neck of the sac in an upward and medial direction, in order to avoid the inferior epigastric vessels. For if he mistakes a direct for an oblique hernia and incises the neck of the sac in a lateral direction, the vessels will be wounded; or if he mistakes an old-standing oblique for a direct hernia and cuts in a medial direction, the same accident will occur.

The *incision* for direct hernia is practically the same as that employed in dealing with the oblique variety (p. 265), but the coverings of the sac are somewhat different. After the external spermatic fascia has been divided, the spermatic cord within its cremasteric and infundibuliform fasciæ is found lying to the lateral side, and the hernia, covered by a thin expansion from the falx inguinalis (conjoined tendon), to the medial side. When this layer is incised the hernial sac is exposed, covered by a sheath which, though derived from the fascia transversalis, is quite distinct from the internal spermatic (infundibuliform) fascia of the cord (Fig. 77).

In the female, the inguinal canal is occupied by the round ligament of the uterus, which is attached to the skin and fascia of the labium majus. In the fœtus, it also lodges a peritoneal process, the *Canal of Nuck*, which corresponds to the processus vaginalis in the male. At birth, the canal of Nuck should be completely closed, but it may remain patent and give rise to inguinal hernia. This condition occurs rarely in adult women, but is not uncommon in female infants and young girls. As the hernia increases in size it drags into its wall a part of the suspensory ligament of the ovary (p. 393), which, at its lateral extremity, is not far distant from the abdominal inguinal ring. As a result the ovary and the distal part of the uterine (Fallopian) tube are often found in the sac.

Imperfect closure of the canal of Nuck may lead to *encysted hydrocele of the round ligament*.

Varicocele is a varicose condition of the veins of the pampiniform plexus (p. 261). In adolescents it is almost invariably on the left side, and many explanations have been suggested. (*a*) The left spermatic vein, which is formed by the union of the pampiniform veins, joins the left renal almost at right angles, whereas the right spermatic vein joins the inferior vena cava very obliquely. It has been urged that, owing to its method of termination, the outflow from the spermatic vein is not so free on the left side as it is on the right. (*b*) The total length of the spermatic vein and pampiniform plexus is less on the right side than the left, since the left testis hangs lower in the scrotum and the left spermatic vein terminates at a higher level. (*c*) The valve at the orifice of the left spermatic vein may be absent. (*d*) The venous return from the left spermatic vein may be obstructed by the pressure of the iliac colon, behind which it passes as it ascends on the iliacus (Fig. 88).

A varicocele on the right side generally indicates that the right spermatic vein is pressed on by some tumour growth.

In this condition the veins of the plexus are much enlarged and very tortuous, and, when they have been exposed (p. 266), they must be separated from the ductus (vas) deferens. The vessels are then ligated above and below and the intervening portion is removed. The ligated ends are then tied together and the coverings of the cord are united over them. In the process the internal spermatic artery is not uncommonly resected, but the testis receives a sufficient supply from the artery to the ductus deferens, which becomes increased in size.

Undescended Testis (see also p. 262).—In embedding an imperfectly descended testis in the scrotum, the preliminary steps are much the same as in the operation for varicocele, but the external oblique aponeurosis may have to be slit up from the subcutaneous inguinal ring. It is generally found that the ductus deferens is sufficiently long to allow the testis to be placed at the bottom of the scrotum, but it will be necessary to divide all the other constituents of the cord, together with its coverings. As the testis increases in size about puberty, operative interference should be undertaken a year or two before that period in order that the circulation, temporarily disturbed by the division of the internal spermatic artery, may be completely and efficiently re-established for the nutrition of the growing organ.

The **Testis** lies obliquely in the scrotum so that the upper pole is antero-lateral to the lower, and the **Epididymis** is closely applied to the lateral aspect of its posterior border. Inside its fascial coverings (p. 259) the testis is invested by a closed peritoneal sac, the *Tunica Vaginalis*. This sac possesses a parietal layer, associated with the coverings (Fig. 81), and a visceral layer, which covers the testis anteriorly, medially, and laterally, but not posteriorly. The epididymis obtains a partial covering from the visceral layer, and the medial aspect of its body is separated from the postero-lateral aspect of the testis by a small peritoneal recess—the sinus epididymidis (digital fossa). In large hydroceles this fossa may become so deep as to separate the two structures completely. Above the testis the tunica vaginalis extends upwards for a short distance on the spermatic cord.

The testis possesses a capsule of connective tissue which is known as the *Tunica Albuginea* (Fig. 81). Anteriorly and on each side it blends with the visceral layer of the tunica vaginalis; posteriorly, where it is in relation to the epididymis and ductus (vas) deferens, it is greatly thickened to form the *Mediastinum Testis*, which sends numerous septa into the body of the testis to join the tunica albuginea. In this way the organ is subdivided into lobules and these contain the *Seminiferous Tubules*. The blood-vessels break up into capillaries on the deep surface of the tunica albuginea and on the sides of the septa.

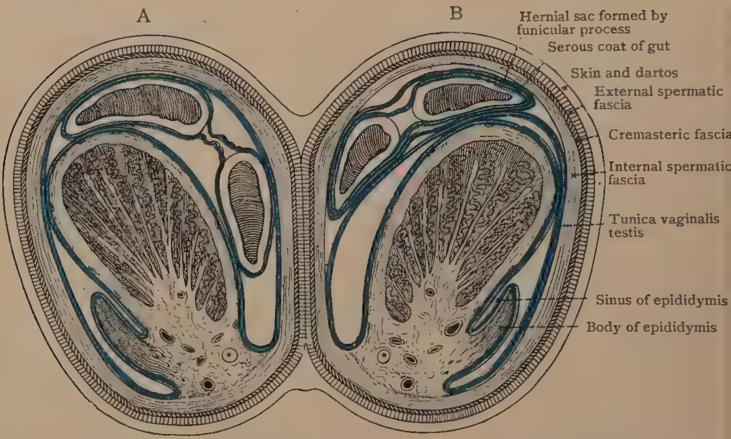
A
B
Hernial sac formed by funicular process
Serous coat of gut
Skin and dartos
External spermatic fascia
Cremasteric fascia
Internal spermatic fascia
Tunica vaginalis testis
Sinus of epididymis
Body of epididymis

FIG. 81.—Diagram of a Transverse Section through the Scrotum and Testes.

A shows the peritoneal relationships of the vaginal type of developmental inguinal hernia. B shows the peritoneal relationships of the funicular type of developmental inguinal hernia.

A corresponds to Fig. 78 (*a*), and B corresponds to an exaggerated condition of Fig. 78 (*d*).

In **Excision of the Testis** two routes are available. The testis may be approached from below by incising the scrotum, or the spermatic cord may be exposed above, as in the operation for varicocele, and, by traction on it, the testis may be dragged up out of the scrotum into the wound. The latter method is preferable in malignant disease, as it enables the surgeon to remove the testis, the spermatic cord, and the associated lymphatics through the same incision. This route is also used in tuberculous disease of the testis when there are no sinuses or adhesions to the scrotum. If the latter conditions are present, the lower route is adopted and the incision is planned so as to excise the involved skin area. This method provides excellent drainage.

The **Epididymis** begins in an enlargement which is situated on the upper pole of the testis. This is termed the *Head* (*globus major*), and it receives the efferent ducts of the testis, which unite to form the convoluted *Ducts of the Epididymis*. The *body*, which contains the downward continuation of the duct, is much narrower than the head, and is closely applied to the lateral aspect of the posterior border of the testis (Fig. 81). Inferiorly, the epididymis again enlarges to form the *Tail* (*globus minor*), and from its medial side the duct emerges as the *ductus* (*vas*) *deferens*, with greatly thickened walls. This structure ascends along the medial side of the epididymis and is closely related to the terminal branches of the internal spermatic artery. At the upper pole of the testis the ductus deferens enters the spermatic cord.

Development of the Testis and Epididymis.—Prior to the development of the permanent kidneys, the embryo possesses two primitive kidneys, the *Wolffian bodies*, which communicate with the cloaca by the *Wolffian ducts*. The testis develops in close relation to the Wolffian body, and, as the Wolffian body atrophies, the efferent ducts of the testis become connected to the Wolffian duct, which forms both the epididymis and the ductus deferens (p. 398). Most of the tubules of the Wolffian body disappear and the few which persist constitute the *Paradidymis or Organ of Giraldes*, which is situated in the lower part of the spermatic cord, just above the head of the epididymis. The *Mullerian ducts*, which play such an important part in the formation of the female generative organs (p. 398), disappear almost entirely in the male. Each is represented by an *Appendix Testis* (*sessile Hydatid of Morgagni*), which lies at the upper pole of the testis just in front of the epididymis. Both the paradidymis and the appendices testis may give rise to cysts, which frequently contain spermatozoa and are termed spermatoceles. The *prostatic utricle* (*sinus pocularis*) represents the fused caudal ends of the two Mullerian ducts.

In **Hydrocele** of the tunica vaginalis, fluid collects in the sac and gradually distends it above, in front, and on each side of the testis, giving rise to a somewhat egg-shaped swelling. The testis and epididymis lie posterior to it, but in rare cases *inversion of the testis* may be present. In this condition the epididymis is related to the anterior border and the tunica vaginalis to the posterior border and lateral surfaces of the testis, while the ductus deferens occupies an anterior position in the cord (Treves). Before tapping a hydrocele it is important to determine the position of the testis with reference to the swelling. The trochar and cannula are pushed through the skin of the scrotum anteriorly in an upward and backward direction. The distended tunica vaginalis is pierced from in front (to avoid the testis) and near its lower pole (to facilitate the evacuation of its contents). Care must be taken not to injure any of the superficial veins, as their dependent position and the relief of tension following the operation may tend to increase the amount of hæmorrhage.

In the *radical cure of a hydrocele* the approach is very similar to that employed in varicocele (p. 266). The hydrocele is pushed upwards into the wound, and the coverings are incised and dissected off. The parietal layer of the tunica vaginalis is cut away along the lines of its reflection on to the testis and epididymis, *or* a vertical incision may be made in the tunica vaginalis anteriorly, and the two halves may then be folded backwards so that their edges can be united behind the epididymis.

Examination of the Testis and Spermatic Cord.—The shape and consistence of the testis can readily be appreciated when it is examined *in situ*, and any alteration of the normal elastic feel, or variation in size or shape, should be carefully observed. The epididymis can be felt along the postero-lateral border. Although it is usually fixed in position, the epididymis can sometimes be moved independently of the testis and yet may be otherwise normal.

Enlargement of the tail (globus minor) of the epididymis is not uncommonly associated with a bacterial infection ascending along the ductus deferens from the urethra, such as occurs in gonorrhœa. Tuberculous disease, on the other hand, usually commences in the head (globus major), as the infection is carried by the blood stream, and the bacilli settle down in the area supplied by the epididymal branches of the internal spermatic artery.

When acutely inflamed, the epididymis becomes sausage-shaped. It is greatly swollen and tends to surround the posterior part of the testis, which, though also enlarged, is rather obscured. On the other hand, in acute inflammatory conditions of the testis, the swelling resembles a Jaffa orange in shape, and the epididymis cannot be easily defined. Both these conditions may be somewhat masked by an associated acute hydrocele.

The ductus deferens can be felt along the postero-medial border of the testis and may easily be distinguished in the spermatic cord owing to its thick muscular wall. In tuberculous disease, the duct is often irregularly thickened and its recognition is still easier; in varicocele, on the other hand, the increased number and size of the veins may render its identification more difficult. The presence of a hernial sac may be made out by grasping the spermatic cord and allowing the individual structures to slip away from between the finger and thumb. If both cords are examined at the same time, the presence of an additional structure on the affected side can often be determined.

In children, the cremasteric muscle may be so strongly developed that it is able to draw the testis up into the inguinal canal. The sudden disappearance from the scrotum of a lump which may as suddenly reappear may lead the mother to suppose that the child is suffering from a rupture, whereas the swelling is simply the testis. Similarly, the condition of undescended testicle may be mistaken for a rupture, if the mother fails to notice the absence of the testis from the scrotum on the affected side. Examination of the mobility of the testis can be carried out by testing the *cremasteric reflex.* Gentle stroking of the skin over the proximal part of the front of the thigh stimulates the sensory branches of the genito-femoral (genito-crural) nerve and causes a reflex contraction of the cremaster, which is supplied by the motor part of the same nerve.

Posterior Abdominal Wall. — The **Lumbo-dorsal (Lumbar) Fascia** is a strong aponeurotic layer which extends between the ribs and the iliac crest. Laterally it gives origin to the internal oblique and the transversus. Medially it splits into three lamellæ. Of these, the posterior reaches the lumbar spines, and the middle the tips of the transverse processes. They enclose between them the large sacro-spinalis (erector spinæ) muscle. The anterior lamella is attached to the anterior aspects of the transverse processes; between it and the middle lamella the quadratus lumborum is situated (Fig. 82).

The posterior lamella of the lumbo-dorsal fascia is covered by the latissimus dorsi, to which it partly gives origin. The lateral margin of this muscle crosses the free posterior border of the external oblique, and, together with a portion of the iliac crest, they enclose the *lumbar triangle of Petit.* The roof of this triangle is formed by the deep fascia of the back, and its floor by the internal oblique (Fig. 74).

The *upper lumbar triangle* lies under cover of the latissimus dorsi, above and to the medial side of the lumbar triangle of Petit. It is bounded above by the twelfth rib; medially, by the lateral margin of the sacro-spinalis; below, by the line of origin of the internal oblique from the lumbo-dorsal fascia, which corresponds to the lower border of the latissimus dorsi. The floor of this space is formed by the lumbo-dorsal fascia. and constitutes the weakest part of the posterior abdominal wall, *Abscesses arising in connection with the vertebral column* lie between the fascial envelope of the abdomen (p. 275) and the lumbo-dorsal fascia (Fig. 83). If the pus bursts through the latter layer, it enters the upper lumbar triangle and then passes downwards and laterally. Escaping from under cover of the latissimus dorsi, it gains the lumbar triangle (of Petit) and points above the iliac crest.

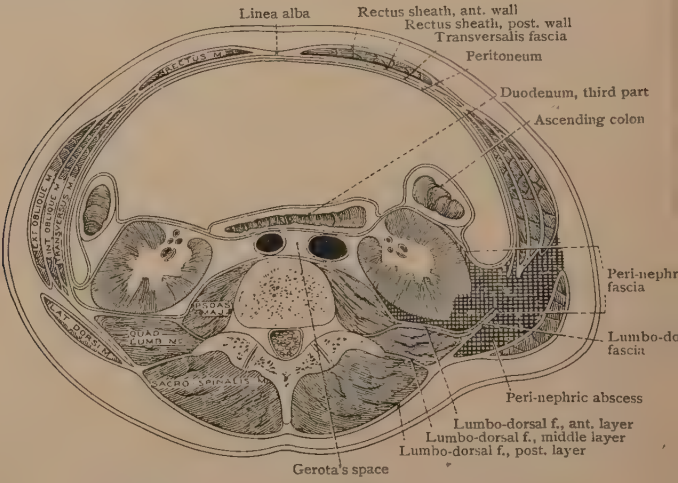
Linea alba
Rectus sheath, ant. wall
Rectus sheath, post. wall
Transversalis fascia
Peritoneum
Duodenum, third part
Ascending colon
Peri-nephr
fascia
Lumbo-do
fascia
Peri-nephric abscess
Lumbo-dorsal f., ant. layer
Lumbo-dorsal f., middle layer
Lumbo-dorsal f., post. layer
Gerota's space
RECTUS M.
EXT. OBLIQUE M.
INT. OBLIQUE M.
TRANSVERSUS M.
PSOAS MAJ.
QUAD. LUMB. M.
LAT. DORSI M.
SACRO SPINALIS

FIG. 82.—Diagram of a Transverse Section through the Abdomen, at the level of the Third Lumbar Vertebra.

On the left side, the normal arrangement of the fasciæ is shown. *On the right side*, the course taken by a peri-nephric abscess is represented. The pus has perforated the peri-nephric and the lumbo-dorsal fasciæ, and, after passing downwards and laterally, has appeared at the lateral border of the latissimus dorsi in the lumbar triangle (of Petit).

Abscesses which arise within the fascial envelope of the abdomen tend to pass forwards round the abdominal wall in the extra-peritoneal fat.

The *Quadratus Lumborum* is a flat muscle arising below from the iliac crest and the ilio-lumbar ligament, which extends between the crest and the transverse process of the fifth lumbar vertebra. It becomes narrower as it passes upwards to be inserted into the twelfth rib. Anteriorly, it is clothed by the anterior lamella of the lumbo-dorsal fascia, which separates it from the medial continuation of the fascia transversalis (p. 275). Both muscles acting together fix the twelfth ribs and so assist the diaphragm in inspiration; one, acting alone, produces lateral flexion of the vertebral column. The nerve-supply is derived from L. 1, 2, 3, and 4.

The *Psoas Major* occupies the groove between the bodies and transverse processes of the lumbar vertebræ. It arises from the twelfth thoracic and all the lumbar vertebræ, and passes downwards and laterally along the margin of the brim of the pelvis. Passing behind the inguinal ligament, it enters the thigh and is inserted into the lesser trochanter (p. 411). This muscle forms a fleshy pad, which separates the kidney from the vertebral column. It receives its nerve-supply from the anterior rami of L. 2 and 3.

The *Iliacus* fills up the hollow on the ventral surface of the ilium and has the psoas major related to its medial border. Most of its fibres are inserted into the psoas tendon. It is supplied by the femoral (ant. crural) nerve.

Both these muscles act together, and when the lower limb is free to move they act as flexors of the hip-joint; when the lower limb is fixed, they act as flexors of the trunk.

The **Fascia Iliaca**, which is continuous above with the fascia transversalis and below with the parietal layer of the pelvic fascia (p. 359), covers both the iliacus and the psoas. It is firmly attached to the iliac crest and to the lateral part of the inguinal ligament. Opposite the femoral vessels, it passes down into the thigh, forming the posterior wall of the femoral sheath (p. 407).

Along the line of origin of the transversus from the lumbo-dorsal fascia, the transversalis fascia becomes adherent to or partially blended with the latter. As it is continued medially, it is separated from the quadratus lumborum by the anterior lamella of the lumbo-dorsal fascia, but it is in direct contact with the psoas major (Fig. 82). At the lateral border of the kidney the transversalis fascia splits to enclose both the kidney and the suprarenal gland, but a fibrous partition separates the two structures so that, when the fascia is incised, the kidney can be drawn out while the suprarenal gland remains in place.

The fascia which surrounds the kidney is termed the *peri-nephric fascia*. It limits a space (Gerota's), which is closed above, below, and to the lateral side, but which is open medially, where both layers are continued across the middle line. They are separated from one another by the renal vessels, the aorta, and inferior vena cava. The two layers meet inferiorly just below the lower pole of the kidney, but they may, abnormally, remain separate for a much greater distance. The latter condition constitutes a predisposing cause of movable kidney (p. 355).

The abdomen possesses a *complete fascial envelope*, which is formed by (1) the fascia transversalis, (2) the diaphragmatic fascia, (3) the peri-nephric fascia, (4) the fascia iliaca, and (5) the pelvic fascia. Prolongations of this fascial envelope form the femoral sheath and the internal spermatic or infundibuliform fascia, which covers the testis and the spermatic cord.

The large blood-vessels of the abdomen and pelvis lie inside the fascial envelope while the great nerves lie external to it.

Psoas Abscess.—A cold abscess resulting from tuberculous periostitis or osteo-myelitis of the lower thoracic or upper lumbar vertebræ is limited in front by the anterior longitudinal ligament and spreads in a lateral direction. In the lumbar region it passes either into the substance of the psoas major or between the muscle and its covering fascia; in the thoracic region it enters the posterior mediastinum and, gravitating downwards, passes into the abdomen behind the medial lumbo-costal arch (int. arcuate ligament), which is simply the thickened upper border of the psoas fascia. In both instances, therefore, the abscess lies behind the psoas fascia, and its presence may excite reflex contraction of the muscle with flexion at the hip-joint. A similar reflex is often observed in appendicular inflammation, and in other cases where the muscle is irritated.

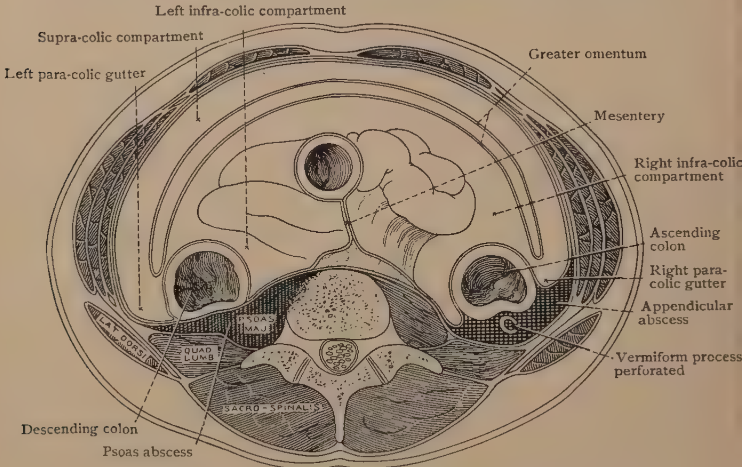
Left infra-colic compartment
Supra-colic compartment
Left para-colic gutter
Greater omentum
Mesentery
Right infra-colic compartment
Ascending colon
Right para-colic gutter
Appendicular abscess
Vermiform process perforated
PSOAS MAJ
QUAD LUMB
LAT DORSI
SACRO-SPINALIS
Descending colon
Psoas abscess

FIG. 83.—Diagram of a Transverse Section through the Abdomen, below the Lower Poles of the Kidneys.

On the left side, a psoas abscess is depicted, spreading laterally behind the fascial envelope of the abdomen. The pus is separated from the quadratus lumborum by the anterior layer of the lumbo-dorsal fascia, and from the descending colon by the transversalis fascia.

On the right side, an abscess is depicted in connection with a retro-cæcal, extra-peritoneal vermiform process. In this case the pus is situated inside the fascial envelope of the abdomen.

Direction of Spread.—(1) The pus may pass *laterally* behind the peri-nephric fascia and in front of the quadratus lumborum (Fig. 83), and so reach the anterior surface of the lumbo-dorsal fascia near the origin of the transversus abdominis (transversalis). At this point the peri-nephric and transversalis fasciæ become continuous, but they are both adherent to the origin of the muscle and check further spread in a lateral direction. The pus may perforate the lumbo-dorsal fascia and enter the upper lumbar triangle, from which it may spread to the lumbar triangle (of Petit) (p. 273).

(2) *The pus may follow the direction of the psoas major* and enter the thigh behind the inguinal ligament. In its course it may infect and erode the sacro-iliac joint, or it may spread to the bursa which separates the tendon of the muscle from the hip-joint. When this bursa communicates with the joint, the latter also may become infected. This condition is referred to again on p. 428.

(3) *The pus may pass downwards* at first and then, spreading *laterally*, gain the iliac fossa where it lies behind the fascia iliaca. Its presence in this situation may be recognised on abdominal palpation. At the iliac crest both the fascia iliaca and fascia transversalis are bound down to the bone, but, should the abscess increase in size, their attachments are not strong enough to limit it to the iliac fossa, and it may come towards the surface near the anterior superior iliac spine. In these cases it is advisable to evacuate the pus, and the muscles may be divided by a grid-iron incision. The transversalis fascia is not incised, but is separated from the transversus muscle until the abscess is reached.

(4) The pus may occasionally pass *backwards*, following the course of the dorsal branch of a lumbar artery. It usually passes medial to the sacro-spinalis and points near the posterior median line, or it may spread upwards and downwards within the sheath of the muscle (Fig. 83).

The Approach to the Kidney from behind.—In nephropexy and other operations which do not necessitate the exposure of the ureter, a *vertical incision along the lateral border of the sacro-spinalis* (*erector spinæ*) gives good access. After the skin and fasciæ have been divided, the oblique lower fibres of the latissimus dorsi are cut across in the line of the incision, exposing the lumbo-dorsal fascia (lumbar aponeurosis), which is also incised vertically. In the upper part of the wound, the posterior layer of the peri-nephric fascia is now exposed, but, below, the lateral margin of the quadratus lumborum, which crosses the wound obliquely (p. 274), must be divided together with the anterior layer of the lumbo-dorsal fascia on its anterior surface. When the edges of the wound are widely retracted, the last thoracic, ilio-hypogastric and ilio-inguinal nerves may be seen running downwards and laterally behind the peri-nephric

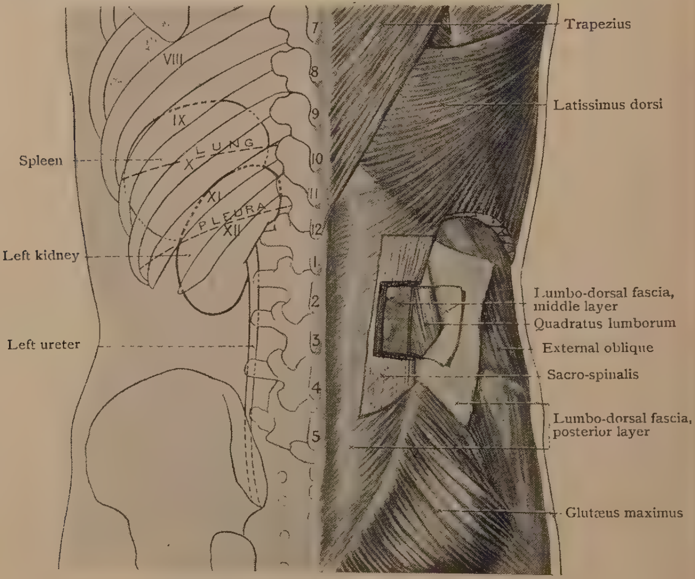
Trapezius
Latissimus dorsi
Spleen
Left kidney
Left ureter
Lumbo-dorsal fascia, middle layer
Quadratus lumborum
External oblique
Sacro-spinalis
Lumbo-dorsal fascia, posterior layer
Glutæus maximus
VIII
IX
X
XI
XII
LUNG
PLEURA
7
8
9
10
11
12
1
2
3
4
5

FIG. 84.—The Position and Posterior Relations of the Kidney.

On the right side, the lower part of the latissimus dorsi has been removed and a rectangular flap of the posterior layer of the lumbo-dorsal fascia has been turned laterally. A part of the sacro-spinalis has been resected, exposing the tips of the transverse processes of the 2nd and 3rd lumbar vertebræ and the middle layer of the lumbo-dorsal fascia. A rectangular flap of the fascia has been turned laterally in order to expose the quadratus lumborum.

On the left side, the relations of the spleen and left kidney to the lung and pleural sac are indicated on the surface.

fascia. When the latter is opened, the peri-renal fat can readily be separated from the kidney with the finger.

When freer access is desired, *e.g.* in exploratory operations necessitating the exposure of the ureter, the *oblique lumbo-ilio-inguinal incision* may be preferred. It commences above in the angle between the twelfth rib and the sacro-spinalis, and is carried downwards and laterally in the direction of the anterior superior iliac spine. If necessary, it may be continued medially above the lateral part of the inguinal ligament, being limited by the abdominal inguinal (int. abd.) ring.

The lower fibres of the latissimus dorsi are cut across, exposing the lumbo-dorsal fascia above and the internal oblique below. These structures are divided in the line of the skin incision, and the lateral part of the wound is deepened through the transversus abdominis until the fascia transversalis is reached. The posterior layer of the peri-nephric fascia, which is the continuation of the fascia transversalis in a medial direction, has already been exposed by the division of the lumbo-dorsal fascia. It is now incised, and the kidney and the commencement of the ureter are found in the peri-renal fat. As the ureter is traced downwards, it becomes necessary to divide the fascia transversalis, which has so far been preserved intact. This is done with great care because, owing to the scantiness of the extra-peritoneal fat in this region, there is danger of opening the peritoneal cavity. In addition, the descending colon is retro-peritoneal and the posterior wall of the gut or its blood-vessels may be injured unless great care is exercised.

When the whole incision is employed, the ureter can be traced from its commencement in Gerota's space through the anterior layer of the peri-nephric fascia into the extra-peritoneal fat, and then downwards to the pelvis.

In the process, the peritoneum is stripped off the posterior abdominal wall and serves to keep the abdominal contents away from the field of the operation.

The danger of opening the pleural sac at the upper end of the wound must also be borne in mind. The lower limit of the sac posteriorly (p. 516) lies in front of the last rib, at the point where the rib is crossed by the lateral margin of the sacro-spinalis. Frequently the last rib is so short that its extremity cannot be felt. In these cases the eleventh rib may be mistaken for the twelfth, and if so, the pleura will be opened at the upper part of the wound as the incision is deepened. This danger can be avoided by counting the ribs from above downwards and so determining whether the lowest palpable rib is the eleventh or the twelfth. Further, on rare occasions, the pleura may lie at a lower level than normal, and cross the apex of the angle between the twelfth rib and the sacro-spinalis. It is then very difficult to avoid opening the pleural sac.

It may be necessary, *e.g.* after radiographic localisation of ureteral calculi, *to expose the ureter* without exploring the kidney, and, in this case, the oblique incision need not extend so high as the angle between the sacro-spinalis and the last rib. The fascia transversalis may be incised as soon as it is reached, and the surgeon then works medially, stripping the peritoneum off the posterior abdominal wall, until the anterior surface of the psoas major is recognised. On the other hand, the fascia transversalis may be left intact and the surgeon works medially, stripping it and the fascia iliaca forwards as a continuous sheet. When the psoas major is reached, the fascia is carefully torn through with the finger-nail. Whatever method is employed the ureter will be found *adherent to the posterior aspect of the peritoneum*, and its presence there can readily be detected if the pulp of the finger is turned forwards and lightly drawn across its course. When it has been separated from the peritoneum, the ureter can be brought up to the surface and incised to permit of exploration with probes or the removal of a calculus. Owing to its rich blood-supply (p. 357), incisions in the ureter soon heal, and, for the same reason, complete isolation of the duct is not followed by damage from sloughing.

THE ABDOMINAL CAVITY.

The differences which exist between the living subject and the dissecting-room cadaver are probably more marked in the abdomen than in any other part of the body. The action of the preservatives used not only renders firm those organs which are pliant in life, such as the liver and the spleen, but also produces shrinkage of the abdominal contents and retraction of the anterior wall. In addition the living peritoneum possesses a certain amount of mobility on the extra-peritoneal fat, and can stretch or be stretched without tearing, but both these characteristic features disappear after death. As a result, the positions of viscera relative to the vertebral column, as found in the cadaver preserved and dissected in the horizontal position, differ somewhat from those which they occupy in the living subject, more especially when the body is in the erect posture.

With the exception of the retroperitoneal viscera, which are practically fixed, the positions of viscera relative to the surface vary within wide limits. The influences which govern these variations are (1) posture, (2) the personal factor, (3) the physiological, and (4) the pathological condition at the time of examination.

The **Peritoneum** is a highly absorptive serous membrane which lines the abdominal and pelvic cavities (*parietal layer*), and is more or less intimately related to the viscera contained by them (*visceral layer*). In the male it forms a completely closed sac, but in the female it communicates with the cavities of the uterus and vagina through the ostium abdominale of the uterine (Fallopian) tube. Infective conditions, therefore, may ascend to the peritoneal sac through the vagina, uterus, and tubes, as, for example, in acute gonorrhœal peritonitis.

The deep surface of the anterior abdominal wall is completely lined by peritoneum. Below the umbilicus it forms an uninterrupted sheet so that when the cavity has been opened the hand may be introduced and passed across to the opposite side without meeting any normal obstruction. Above the umbilicus, a fold of peritoneum, consisting of two layers—**the falciform ligament**—passes backwards to the liver and forms an imperfect partition. Its lower border, where the two constituent layers become continuous, is free and contains the *ligamentum teres* and the associated para-umbilical veins (p. 247). Although its anterior attachment is in the middle line, the falciform ligament passes backwards and slightly to the right. On this account, when supra-umbilical median incisions are enlarged in a downward direction, they should be carried round the *left* side of the umbilicus, so as to obviate the necessity for cutting through the ligamentum teres and the associated veins.

The peritoneum lining the anterior abdominal wall sweeps upwards on to the inferior surface of the diaphragm, and is then reflected on to the liver (Fig. 85) and stomach. Between the hepatic and gastric reflections, the peritoneum on the under surface of the diaphragm becomes continuous with the anterior layer of the lesser omentum.

In Fig. 85 the peritoneum is shown passing from the diaphragm to the liver in two layers, which cover its anterior and posterior surfaces and meet on the inferior surface at the porta hepatis (transverse fissure). They then descend to the lesser curvature of the stomach as a broad sheet which is termed the **lesser omentum**. After enclosing the stomach and constituting its serous coat they again meet one another, and descend for a variable distance towards the pelvis. Inferiorly they are folded sharply upwards and ascend to the transverse colon. This large peritoneal sheet, which connects the transverse colon to the stomach, is termed the **greater omentum**.

Originally it consisted of two layers above and four layers below, as shown in Fig. 85, but these layers may become completely fused, and in the living subject it is not always possible to distinguish more than one layer.

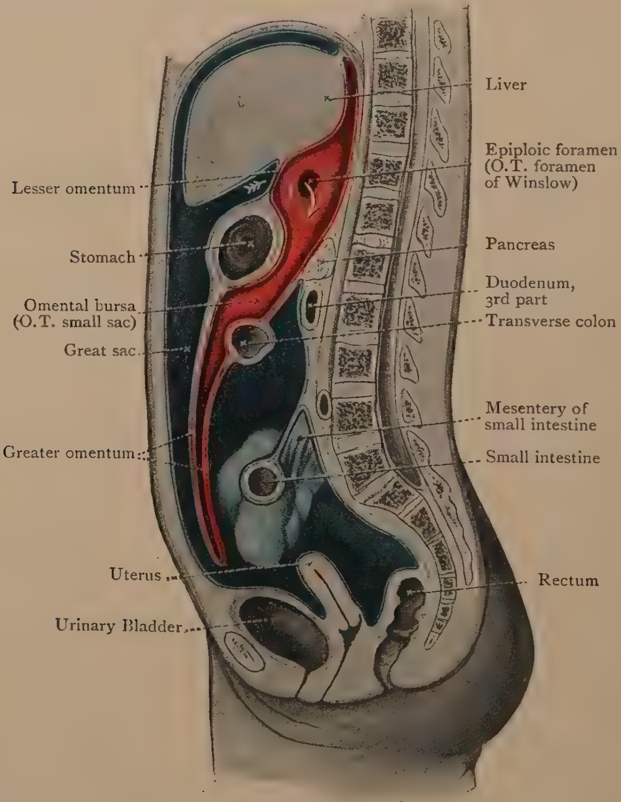
Liver
Epiploic foramen (O.T. foramen of Winslow)
Lesser omentum
Pancreas
Stomach
Duodenum, 3rd part
Omental bursa (O.T. small sac)
Transverse colon
Great sac
Mesentery of small intestine
Greater omentum
Small intestine
Uterus
Rectum
Urinary Bladder

FIG. 85.—Sagittal Section of Abdomen showing the arrangement of the Peritoneum.

The two posterior layers of the greater omentum, having enclosed the transverse colon, pass backwards and upwards to the posterior abdominal wall, as the **transverse meso-colon**, and there they separate along the anterior border of the pancreas on a level with the second lumbar vertebra. The superior layer passes upwards over the posterior abdominal wall and is then reflected forwards on to the liver. The inferior layer passes downwards and forms a complete covering to the posterior abdominal wall below the pancreas. Along a line passing obliquely downwards and to the right, it is lifted off the wall to form the **mesentery**, which encloses the jejunum and ileum. After covering the pelvic viscera (p. 361), this layer passes upwards on the anterior abdominal wall.

It will be seen from Fig. 85 that a portion of the peritoneal cavity is shut off behind the stomach. This is the **Omental Bursa (Lesser Sac)**. It is a developmental diverticulum (p. 307) of the great sac, with which it communicates through a single opening, the **epiploic foramen (of Winslow)**.

The **Greater Omentum** forms a protective covering over the abdominal viscera below the level of the stomach. It contains a variable amount of fat, and is usually the first structure seen when the abdomen is opened. The lower and the lateral margins are free, and it can therefore be easily moved about in abdominal operations. In addition, the greater omentum wanders to any region of the abdomen where inflammatory processes exist, and the surrounding adhesions which it forms are of great value in limiting the spread of infection. On this account it has been termed by Morison the "policeman of the abdomen."

The **Lesser Omentum** passes from the lesser curvature of the stomach and the corresponding border of the first inch and a half of the duodenum to the porta (transverse fissure) of the liver. The two layers of which it consists are closely applied to one another, and form a thin, transparent sheet, save near the right border where they are separated by the portal vein, bile-duct, and hepatic artery. Round this border, which is free and unattached, the two layers become continuous (Fig. 86). Occasionally the lesser omentum is continued beyond the vessels and duct, and receives attachment to the inferior surface of the gall-bladder. Its free border may then be traced downwards over the duodenum to the transverse colon, and on this account the additional part is called the *hepato-colic ligament*. It contains no vessels of any size, but the gall-bladder lies within its upper attachment. It may be cut through parallel to the gall-bladder in exploring the epiploic foramen.

The **Epiploic Foramen (of Winslow)** lies behind the right free border of the lesser omentum. It is bounded above by the liver (caudate lobe), and behind by the peritoneum which covers the inferior vena cava. Below it is limited by the first part of the duodenum. In certain cases, *e.g.* examination of the bile-duct, it is necessary to explore the epiploic foramen. This can be effected by passing the finger backwards and to the left along the postero-lateral surface of the gall-bladder till it reaches the neck. The finger then slips behind the right margin of the lesser omentum and enters the foramen.

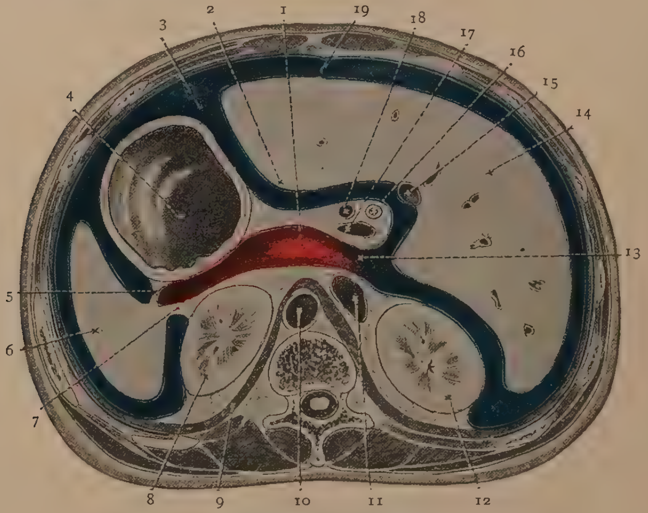

FIG. 86.—Transverse Section of Abdomen at the level of the Epiploic Foramen (of Winslow).

1. Omental bursa (O.T. small sac).
2. Omental tubercle of liver.
3. Great sac.
4. Stomach.
5. Gastro-splenic ligament (O.T. gastro-splenic omentum).
6. Spleen.
7. Lieno-renal ligament.
8. Left kidney.
9. Diaphragm.
10. Aorta.
11. Inferior vena cava.
12. Right kidney.
13. Epiploic foramen (O.T. foramen of Winslow).
14. Liver.
15. Gall-bladder.
16. Bile-duct.
17. Portal vein.
18. Hepatic artery.
19. Falciform ligament.

The **Omental Bursa (Lesser Sac)** extends upwards between the liver and the diaphragm to the upper end of the caudate (Spigelian) lobe (Fig. 85). Below it rarely extends beyond the transverse colon, owing to the fusion of the anterior and posterior layers of the greater omentum. Its anterior wall is formed, from above downwards, by (1) the liver, (2) the lesser omentum, (3) the postero-inferior surface of the stomach, and (4) the two anterior layers of the greater omentum. Its posterior wall is formed, from below upwards, by (1) the transverse colon, (2) the transverse meso-colon, (3) the anterior surface of the pancreas, and (4) the upper pole of the left kidney, the left suprarenal gland, and the diaphragm.

When a transverse section is made through the abdomen so as to pass through the epiploic foramen, the connection of the omental bursa with the great sac is at once demonstrated (Fig. 86). On the left side, at this level, the two layers of peritoneum which enclose the stomach pass backwards from the fundus to form the *gastro-splenic ligament*. At the hilum of the spleen, the lateral (originally anterior) layer gives a complete investment to that organ, which therefore projects into the supra-colic compartment of the peritoneal cavity. From the hilum, the two layers pass backwards to the left kidney as the *lieno-renal ligament* and then they diverge, the one lining the great sac and the other the omental bursa. These two folds, together with the hilum of the spleen, form the left boundary

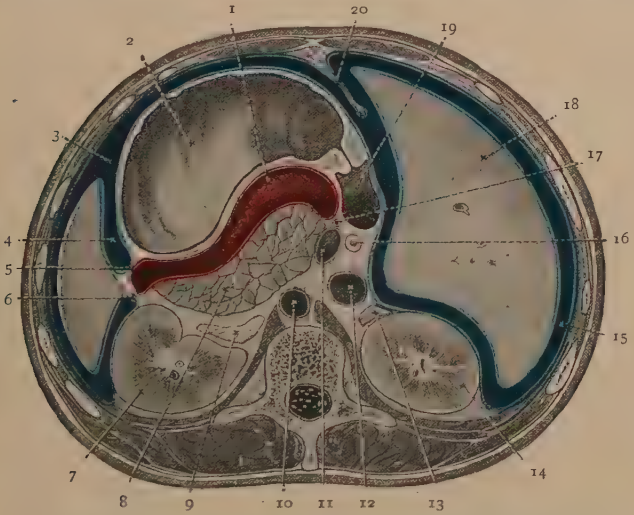

FIG. 87.—Transverse Section of Abdomen, immediately below the Epiploic Foramen.

1. Omental bursa (O.T. small sac).
2. Stomach. 3. Great sac. 4. Great sac.
5. Gastro-splenic ligament (O.T. gastro-splenic omentum).
6. Lieno-renal ligament.
7. Left kidney.
8. Pancreas.
9. Left suprarenal gland.
10 Aorta. 11. Portal vein.
12. Inferior vena cava.
13. Right suprarenal gland.
14. Right kidney.
15. Great sac.
16. Bile-duct.
17. Gastro-duodenal artery.
18. Liver.
19. Duodenum, 1st part.
20. Falciform ligament.

of the omental bursa and completely shut it off from the great sac on this side. Below the level of the spleen, the gastrosplenic ligament is directly continuous with the two anterior layers of the greater omentum, *i.e.* there is no break in the continuity of the wall of the bursa.

Transverse sections made through the omental bursa below the epiploic foramen show it as a completely closed sac. In Fig. 87 the section passes through the pylorus and the first part of the duodenum. The peritoneum on the posterior aspect of the stomach passes to the right and covers rather less than the first inch of the duodenum before it passes backwards on to the head of the pancreas.

This reflection forms the right border of the omental bursa, and the hepatic artery passes forwards round it in order to reach the lesser omentum.

Drainage of the Peritoneal Cavity.—Collections of fluid in the peritoneal cavity differ in situation according to the position of the patient, and, unless they are limited by adhesions, they spread in a downward direction when the patient is in the erect or semi-sitting posture. In the supine position they will tend to pass upwards towards the diaphragm. In the post-operative treatment of inflammatory effusions the patient is usually placed in the Fowler (semi-sitting) position in order to diminish the risk of upward spread into the sub-diaphragmatic region (p. 287).

The peritoneal cavity is naturally subdivided into the pelvis and the abdomen proper, and the latter is further subdivided by the large sheets of peritoneum which form the greater omentum and the mesentery.

The uppermost or **Supra-colic Compartment** lies above and in front of the greater omentum. It is partially subdivided into a right and a left half by the falciform ligament of the liver, and its contents include the liver, the gall-bladder, the stomach, the first part of the duodenum, the spleen, and the upper poles of both kidneys. The omental bursa (lesser sac) may be regarded as a large diverticulum of the supra-colic compartment. In addition other, smaller, recesses occur: (1) between the upper surface of the liver and the under surface of the diaphragm (Fig. 85); (2) the hepato-renal recess of Morison, between the under surface of the liver above and the right kidney and the right (hepatic) flexure of the colon below; and (3) between the spleen and the left kidney.

Anteriorly, the supra-colic compartment is bounded by the anterior abdominal wall; posteriorly, it is limited by the lesser omentum, stomach, and greater omentum, which together form an oblique surface, sloping backwards and to the right. When pus or septic fluid, *e.g.* from a leaking ulcer of the duodenum or anterior wall of stomach, is present in this compartment, it may remain localised owing to adhesions between the greater omentum and the anterior abdominal wall. Its downward spread is thus prevented, and owing to the slope of the posterior wall, the fluid tends to pass into the hepato-renal recess. With the body in the horizontal position it readily spreads from this situation round the free border of the right triangular (lateral) ligament of the liver into the recess between the liver and the diaphragm. The infection of this *intra-peritoneal subphrenic area* is a very serious condition, because the lymphatics of the peritoneum on the under surface of the diaphragm communicate very freely with those of the pleura, and empyæma or abscess of the lung may complicate the existing peritonitis, with fatal results.

The *hepato-renal recess of Morison* may be drained through an incision made below the twelfth rib and at the lateral margin of the kidney. This pierces, in turn, the skin, fasciæ, latissimus dorsi, the obliques, transversus, transversalis fascia, and peritoneum. A tube thus passed into the recess affords good drainage if the patient is placed in the Fowler (semi-sitting) attitude. In this way the spread of infection into the subphrenic danger zone may be successfully prevented.

After perforation of an ulcer on the posterior wall of the stomach, the fluid may be prevented from escaping from the omental bursa by adhesions closing the epiploic foramen (of Winslow). The bursa then becomes distended and may best be drained by means of a tube passed through the lesser omentum from the median incision, which is employed in such cases (p. 298). In addition a counter opening may be made in the left side, below the twelfth rib and lateral to the descending colon, and a tube passed upwards and medially in front of the left colic flexure may be introduced into the bursa through the lower part of the gastro-splenic ligament.

If the epiploic foramen is patent, the fluid passes out into the supra-colic compartment and at once invades the hepato-renal recess of Morison (Fig. 86). In this case, both the recess and the bursa will require to be drained.

The **Infra-colic Compartment** lies behind the greater omentum, transverse colon, and meso-colon, and is subdivided into two, a right and a left, by the mesentery, which extends from the left side of the second lumbar vertebra downwards

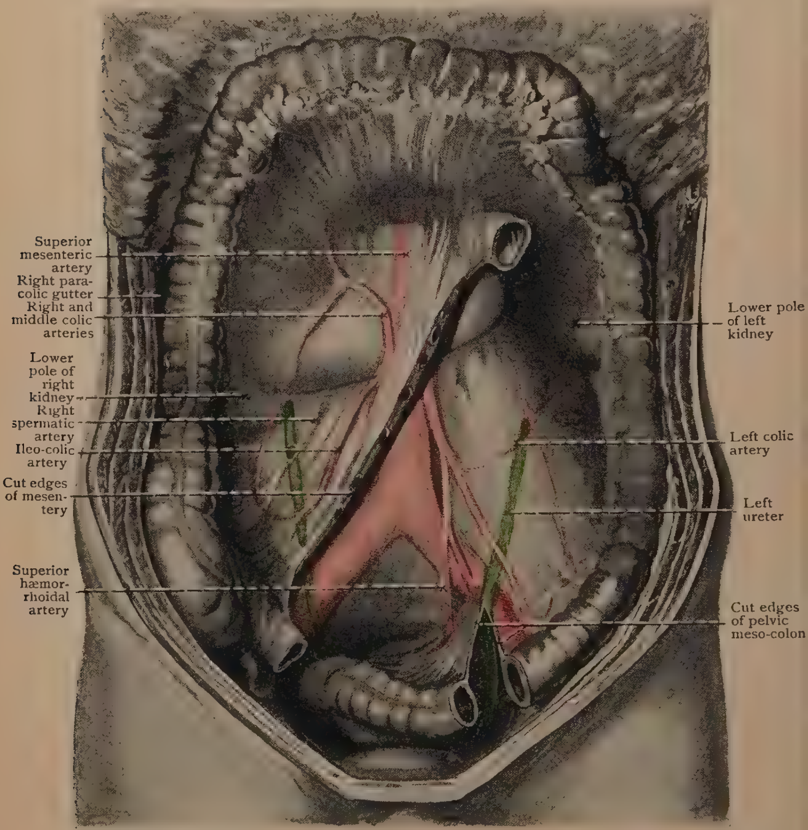
Superior mesenteric artery
Right para-colic gutter
Right and middle colic arteries
Lower pole of right kidney
Right spermatic artery
Ileo-colic artery
Cut edges of mesentery
Superior hæmorrhoidal artery
Lower pole of left kidney
Left colic artery
Left ureter
Cut edges of pelvic meso-colon

FIG. 88.—The Posterior Wall of the Infra-colic Compartment. The greater omentum and the transverse colon have been thrown upwards. The mesentery has been divided close to its root and removed together with the coils of the jejunum and ileum. A small part of the pelvic colon and its mesentery has been resected to expose the pelvic portion of the left ureter.

and to the right for about six inches and terminates at the ileo-colic junction. Coils of small intestine occupy both subdivisions, and must be displaced when the compartment is being explored. This displacement, to be effectual, must be at right angles to the line of mesenteric attachment, *i.e.* upwards and to the right or downwards and to the left. Owing to the " lie " of the mesentery, endeavours to draw the gut downwards and to the right or upwards and to the left cannot meet with much success.

The *right infra-colic compartment,* bounded above by the root of the transverse meso-colon, to the right by the ascending colon, and to the left by the root of the mesentery, is roughly triangular in shape (Fig. 88). It can be exposed by drawing the greater omentum upwards and displacing the coils of small intestine downwards and to the left. The peritoneum on its posterior wall covers the lower pole of the right kidney, the second and third parts of the duodenum, a small part of the head and neck of the pancreas, and the right ureter and psoas major muscle (Fig. 88).

Owing to the protection which it receives from the greater omentum, this compartment is rarely infected by a downward spread, and as its lower extremity is closed (Fig. 88), it is not commonly infected by an upward spread from the pelvis. Primary infection is rare; it is usually due to the vermiform process (p. 335). Drainage may be obtained through the appendicular wound by means of a tube passed upwards and to the left, medial to the ascending colon and behind the greater omentum.

The *left infra-colic compartment* is bounded to the right by the root of the mesentery and to the left by the descending and iliac cola; below, it is bounded on the left side by the ascending part of the pelvic meso-colon, but on the right side it opens freely into the pelvis (Fig. 88). It can be exposed by drawing the greater omentum upwards and displacing the small intestine upwards and to the right. The peritoneum on its posterior wall covers the lower pole of the left kidney, the inferior surface of the body of the pancreas, and the duodeno-jejunal flexure above; the left ureter, the inferior mesenteric and superior hæmorrhoidal vessels, and the left psoas major below.

Either infra-colic compartment may be the site of a tuberculous abscess, following the breaking down of caseous mesenteric lymph glands.

The **right para-colic gutter** lies along the lateral side of the ascending colon, and its floor is formed by the peritoneal reflection from the gut to the lateral wall of the abdomen. Above, it opens into the hepato-renal recess of Morison; below, it passes round or behind the cæcum and communicates with the pelvis over the medial border of the psoas major. Infection of this gutter may occur by downward spread from Morison's pouch and the omental bursa, and this condition may be suspected in those cases of perforated gastric or duodenal ulcer in which pain is felt over the right iliac fossa. Owing to the presence of this channel, stomach contents may be found in the pelvis, even when the greater omentum is adherent to the anterior abdominal wall. Pus from a retro-cæcal (intra-peritoneal, p. 337) abscess may spread upwards along the right para-colic gutter into the loin and possibly to the subphrenic danger zone.

Drainage is conveniently carried out through a stab wound just above the iliac crest by means of a tube, which can be drawn out in front through the appendicular incision. The wound must be on the lateral side of the ascending colon, and great care must be taken to avoid injuring the gut.

The **left para-colic gutter** extends along the lateral side of the descending and iliac cola and opens freely into the pelvis at its lower end. Its upper extremity is separated from the spleen and the lieno-renal recess by the *phrenico-colic ligament,* a fold of peritoneum which passes laterally from the left colic (splenic) flexure to the diaphragm. It may be infected from the supra-colic compartment or by upward spread from the pelvis. Drainage may be obtained through a small gridiron incision in the left iliac fossa, and a stab wound similar to that employed on the right side. A tube may then be passed through from back to front.

The basin of the **Pelvis** is formed by the utero-rectal pouch in the female and by the recto-vesical pouch in the male. Primary infection is due to pathological conditions of the vermiform process (p. 334) or the pelvic viscera. Secondary infection is extremely common, as both para-colic gutters, the supra-colic compartment (in the absence of omental adhesions), and both infra-colic compartments drain into the pelvis.

In the female, owing to the peritoneal relations of the vagina (p. 391), the pelvis may be drained through an incision in the upper part of the posterior fornix. It has been suggested that, in the male, drainage may be obtained through an incision into the rectum from the bottom of the recto-vesical pouch. The usual method, however, is to drain by means of tubes passed downwards and backwards from a median supra-pubic incision, or downwards and medially from iliac gridiron incisions.

In all cases of pelvic inflammation, the patient is placed in the Fowler (semi-sitting) posture, and the assistance of gravity is obtained to prevent the upward spread into the various compartments of the abdomen proper.

Congenital Herniæ.—In a three weeks' human embryo, the alimentary canal may be subdivided into the fore-gut, the mid-gut, and the hind-gut (Fig. 89). They form a tube, which is closed at its cephalic and caudal ends, but which communicates with the yolk-sac through the *vitello-intestinal duct.* At the junction of the mid- and the hind-gut, the *allantois* forms a short blind diverticulum which grows into the body-stalk. At this period the mesoderm lining the cœlom, or body-cavity, of the embryo is directly continuous with the mesoderm lining the cavity—*exo-cœlom*—in which the yolk-sac lies, and consequently the two spaces communicate with one another. The anterior or cephalic part of the cœlom is destined to form the pleural and pericardial sacs, while the rest becomes the peritoneal cavity. As the amnion (Fig. 89), which at first lies dorsal to the embryo, grows round its ends and sides, the exo-cœlom is encroached on, and the body-stalk is brought closer to the yolk-sac. In this way the umbilical cord is formed, and at first it contains the yolk-sac, the rapidly narrowing vitello-intestinal duct, and the remains of the exo-cœlom in addition to the blood-vessels of the body-stalk, the whole being surrounded by the amnion (Fig. 90).

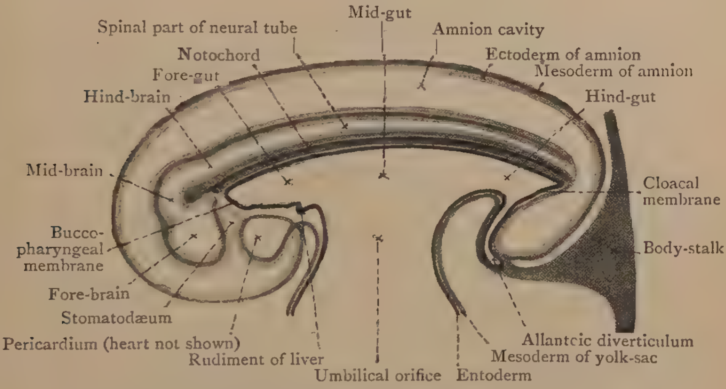
Mid-gut
Spinal part of neural tube
Amnion cavity
Notochord
Ectoderm of amnion
Fore-gut
Mesoderm of amnion
Hind-brain
Hind-gut
Mid-brain
Cloacal membrane
Bucco-pharyngeal membrane
Body-stalk
Fore-brain
Stomatodæum
Allantcic diverticulum
Pericardium (heart not shown)
Mesoderm of yolk-sac
Rudiment of liver
Umbilical orifice
Entoderm

FIG. 89.—Schema of Sagittal Section of Embryo, after the formation of the Head and Tail Folds.

As the abdominal part of the alimentary canal increases in length, it drags the peritoneum away from the dorsal wall, and so acquires a dorsal mesentery. A loop of gut is thus formed, and as the abdominal walls do not grow at the same rapid rate, it descends through the large patent umbilicus and lies in the exo-cœlom within the umbilical cord. At the end of the third month the abdominal cavity is large enough to contain all its viscera, and the intestinal loop returns into the abdomen. The exo-cœlom then becomes completely obliterated, and no trace of it should be found in the umbilical cord at birth. Thus during the second and third months the human embryo normally possesses an umbilical hernia. If the loop of gut fails to return within the abdomen, or if the exo-cœlom remains patent and retains its connection with the peritoneal cavity, a *congenital umbilical hernia* will result.

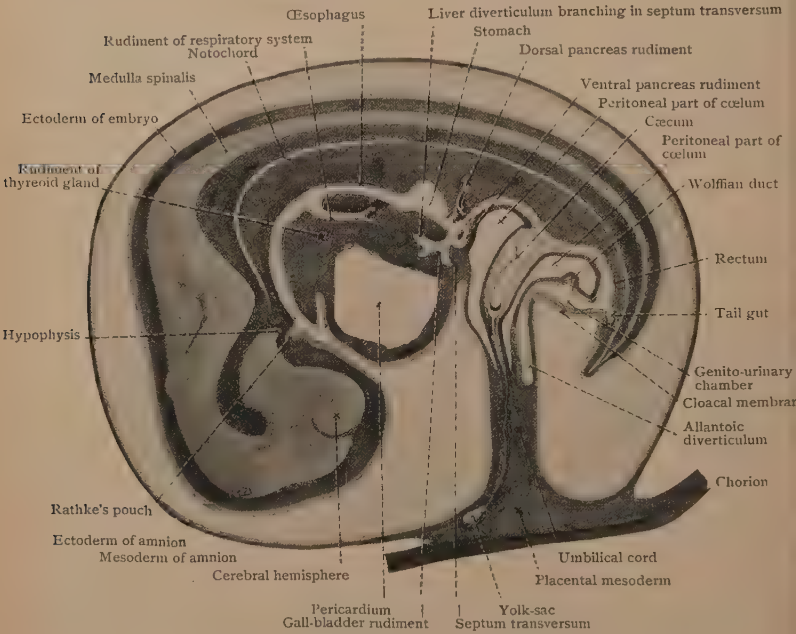
Œsophagus
Liver diverticulum branching in septum transversum
Stomach
Rudiment of respiratory system
Notochord
Dorsal pancreas rudiment
Medulla spinalis
Ventral pancreas rudiment
Peritoneal part of cœlum
Ectoderm of embryo
Cæcum
Peritoneal part of cœlum
Rudiment of thyreoid gland
Wolffian duct
Rectum
Tail gut
Hypophysis
Genito-urinary chamber
Cloacal membran
Allantoic diverticulum
Chorion
Rathke's pouch
Ectoderm of amnion
Mesoderm of amnion
Cerebral hemisphere
Umbilical cord
Placental mesoderm
Pericardium
Gall-bladder rudiment
Yolk-sac
Septum transversum

FIG. 90.—Schema of a Sagittal Section through a Human Embryo, after the rotation of the intestinal loop.

Congenital diaphragmatic hernia is due to imperfect development of the septum transversum, which ought to separate the pleural and peritoneal sacs completely from one another.

The site of the hernia lies postero-lateral to the œsophageal opening in the diaphragm, as this is normally the last part of the diaphragm to develop.

Congenital inguinal hernia is dealt with on p. 263.

The **Stomach** is almost completely invested by peritoneum, and consequently possesses a wide range of movement. Its proximal or *cardiac end*, however, is firmly fixed in position owing to its continuity with the œsophagus. It lies behind the seventh left costal cartilage one inch from the median plane, and at a depth of four inches from the anterior surface of the body. On the posterior surface the cardia can be mapped out at a distance of one inch to the left of the ninth thoracic spine.

The **fundus** of the stomach is that part of the organ which lies above and to the left of the cardia, when the body is in the supine position. It bulges upwards into the left cupola of the diaphragm, and its upper limit reaches the fifth rib behind the pericardium and apex of the heart. Distention of the fundus with gas may mechanically produce cardiac discomfort by direct pressure. In the erect position, the upward projection of the fundus is diminished, and it tends to become absorbed into the greater curvature.

The long axis of the stomach is directed downwards, forwards, and to the right. Its *antero-superior surface* is directed upwards and forwards and lies in relation to the left half of the diaphragm and the inferior aspect of the liver. A large part of this surface, which lies medial to the left costal margin and below the inferior border of the liver, is in direct contact with the anterior abdominal wall. The whole surface helps to form the posterior wall of the supra-colic compartment, which is therefore infected by the perforation of a gastric ulcer situated in this part of the stomach.

The *postero-inferior surface* of the stomach looks downwards and backwards, and is in relation with a number of structures, which constitute the stomach-bed. In its upper part, this surface is in contact with the left half of the diaphragm, the left kidney, the left suprarenal gland, and the spleen; its lower part rests on the pancreas, the transverse meso-colon, and the transverse colon. The two latter structures are supported inferiorly by the underlying coils of small intestine, and together with the pancreas, they form a ledge, sloping downwards and forwards.

The **Greater Curvature** forms the anterior, or inferior, border of the stomach. With the body in the horizontal position, it commences on the fundus (p. 293), cuts the left costal margin at the tip of the ninth costal cartilage, descends not infrequently almost to the umbilicus, and then ascends to the pylorus (*vide infra*); in the erect posture it descends to the umbilicus, and sometimes to a lower level. Along the greater curvature, the two layers of peritoneum which clothe the stomach pass downwards to form the greater omentum, and on the left side they pass backwards to the spleen as the gastro-splenic ligament.

The **Lesser Curvature** forms the upper or posterior border of the stomach. It passes downwards and to the right from the cardiac orifice to the pylorus, curving round the tuber omentale of the liver. It can be mapped out on the surface by a line, concave upwards and to the right, joining these two points. In the erect posture this line becomes more nearly J-shaped owing to the descent of the pylorus and the fixation of the cardiac end of the stomach. Along the lesser curvature the lesser omentum leaves the stomach and passes to the liver and diaphragm.

The distal or pyloric portion of the stomach includes the *pyloric antrum*, the *pyloric canal*, and the *pylorus*. The pyloric antrum is a secondary dilatation of the stomach and is placed proximal to the pyloric canal. The latter is tubular in shape and is about one inch long. It communicates with the duodenum through the pylorus.

With the body in the supine position and the stomach moderately distended, the **Pylorus** lies on the transpyloric plane, half an inch to the right of the middle line; but when the erect posture is adopted, it may sink down to the level of the third lumbar vertebra. In Fig. 91, where the radiogram was taken in the vertical position, the pylorus is seen at that level. At a subsequent operation it was found that, with the change of posture, it had ascended to the transpyloric plane.

The anterior surface of the pylorus lies in contact with the liver, which hides it from view when the abdomen is opened.

The **Position of the Stomach** is subject to wide variations. It is affected by (1) attitude, (2) respiration, (3) the tonus of the anterior abdominal wall, and (4) its contents and those of the small intestines and transverse colon. In addition, apart from differences due to pathological conditions, there is a large range of individual variation.

When the body assumes the erect posture, the postero-inferior surface of the stomach slides downwards and forwards on the sloping ledge which supports it. This movement is rendered possible by the accompanying slight descent of the diaphragm and the elasticity and loose attachment of the living

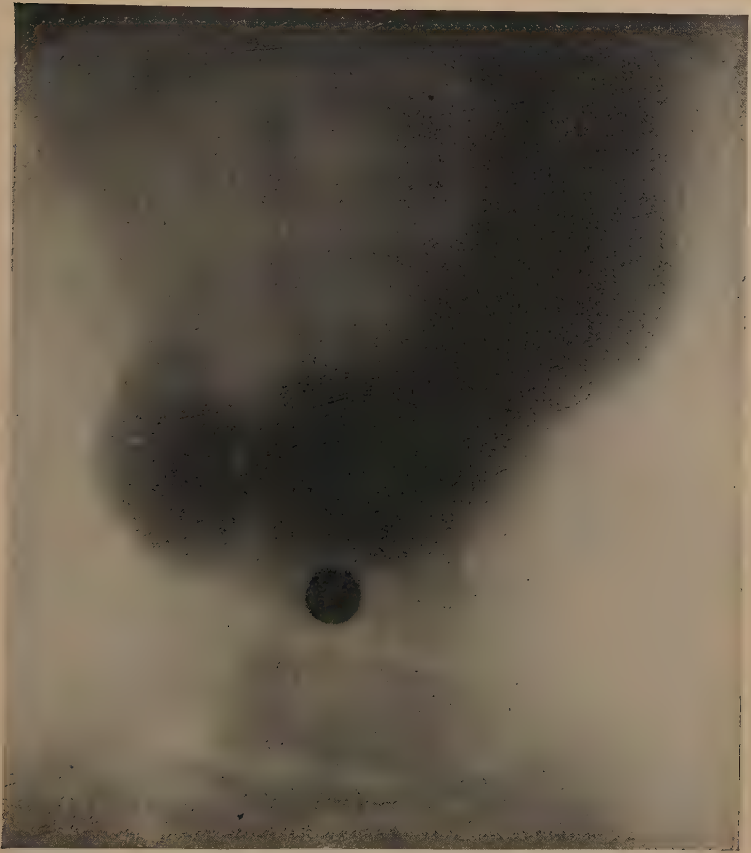

FIG. 91.—Normal Hypertonic Stomach. The black circle is on the umbilicus, and the pylorus lies to the right side of the body of the third lumbar vertebra.

peritoneum (p. 280). At the same time the pylorus undergoes a similar change of position, which is permitted not only by the two factors just mentioned, but also by the mobility of the first inch of the duodenum. Owing to the constancy with which this downward movement has been observed in radiograms taken with the body erect, the presence of the pylorus on the transpyloric plane in such a photograph at once suggests the probability of its immobilisation by adhesions in the pyloro-cystic region (Fig. 92).

FIG. 92.—High Position of the Pylorus. At the subsequent operation adhesions were found fixing the pylorus to the liver, gall-bladder, and neighbouring structures. The black circle is on the umbilicus (fourth lumbar vertebra).

Traube's Space corresponds to that part of the stomach which is in direct contact with the diaphragm and under cover of the costal margin. It is bounded (Fig. 150) above and to the right by the inferior margin of the left lobe of the liver ; above, by the lower margin of the left lung; and behind, by the anterior border of the spleen. Below, it is limited by the costal margin.

The upper part of this area is overlapped by the left pleural sac, but this does not alter the tympanitic stomach note which is obtained on percussion. Enlargement of the left lobe of the liver encroaches on Traube's space from the right side; enlargement of the spleen encroaches on it from the left side; and pleuritic effusions encroach upon it from above.

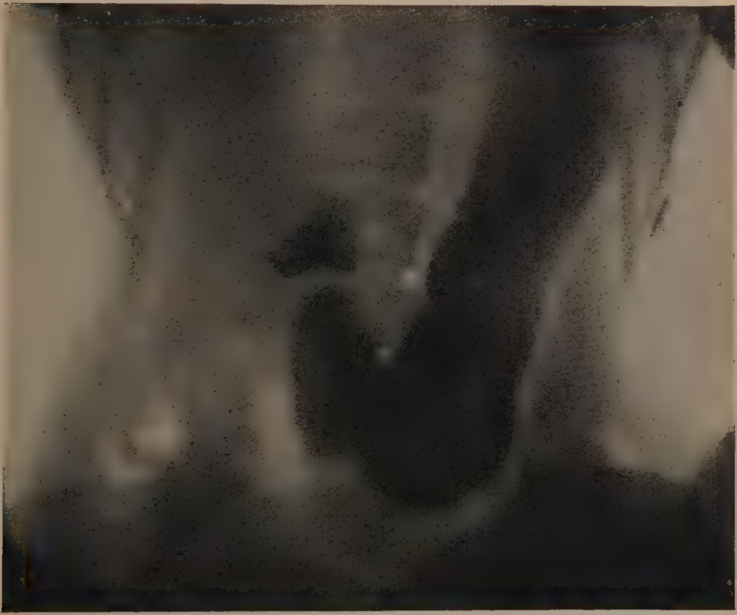

FIG. 93.—Radiogram of Stomach, showing typical J outline. The bismuth is well supported by the muscular tonus, and the duodenal "cap" is well seen immediately above the clear area which denotes the pylorus.

Structure of the Stomach.—The peritoneum gives the stomach a complete *serous coat*, except along the curvatures and also over a small area which is in direct contact with the diaphragm, to the left of the cardia. The *muscular coat* consists of three layers of involuntary muscle: an outer longitudinal, an intermediate circular, and an inner oblique stratum. The circular layer is greatly thickened at the pylorus to form a sphincter, and may, in infants, give rise to congenital stenosis of the pylorus, either by continued spasm or by actual hypertrophy. The *mucous coat* is very thick and highly vascular, and it is thrown into numerous folds, save when the stomach is distended.

Radiographic Examination of the Stomach.—The normal stomach gives a J-shaped shadow in radiograms taken in the erect posture after a bismuth meal. The longer limb of the J is vertical and lies to the left of the middle line. The bismuth, being supported by the tonicity of the healthy stomach wall, reaches a higher level in the longer than it does in the shorter limb, which corresponds to the pyloric antrum (Fig. 93). In atony of the stomach this support is withdrawn, and the fluid adopts a uniform horizontal level.

In some radiograms a small cap-like shadow may be seen immediately above the bismuth in the pyloric antrum and separated from it by a clear area. This is due to the bismuth contained in the first inch of the duodenum, and the clear area corresponds to the pyloric canal, which is closed by the contraction of the pyloric sphincter (Fig. 93).

The Examination of the Living Stomach.—When the abdomen has been opened, preferably in the median plane above the umbilicus, the greater omentum is usually at once exposed and the transverse colon may be seen shining through it. The omentum is traced upwards till the greater curvature is recognised, and the stomach may then be drawn downwards and towards the left in order to permit the pylorus and the first part of the duodenum to be examined. In the healthy stomach the walls are firm, and the muscular thickening which marks the pyloro-duodenal junction renders its recognition easy; but in the atonic stomach the walls are flaccid and thinner, and the pylorus is more difficult to identify. In these cases the pyloric veins which run across the anterior surface of the gut, serve as a guide to the site of the pyloro-duodenal junction (Mayo). The cardiac end and fundus can be examined, but owing to the fixation of the former they cannot easily be brought into view. By drawing the stomach downwards and to the right, most of the greater curvature can be inspected.

In searching for the site of a perforated ulcer, the whole of the antero-superior surface of the stomach and the anterior surface of the first part of the duodenum must be examined.

If gastric contents are not found in the supra-colic compartment when the abdomen is opened, the postero-inferior surface of the stomach must be exposed and examined. Before doing so, the surgeon explores the epiploic foramen (of Winslow), and if it is found closed by adhesions, the diagnosis of a perforated ulcer leaking into the omental bursa may be made with some confidence. In order to gain access to the postero-inferior surface of the stomach, it is necessary to open into the omental bursa. This can be done by carefully tearing through the greater omentum about three inches to the left of the pylorus and immediately below the gastro-epiploic vessels (p. 300). The greater curvature is then turned forwards and upwards, and, as a result, a large part of the postero-inferior surface of the stomach can be both seen and felt through the opening in the omentum. The cardia and the upper part of this surface may be examined by tearing through the thinnest part of the

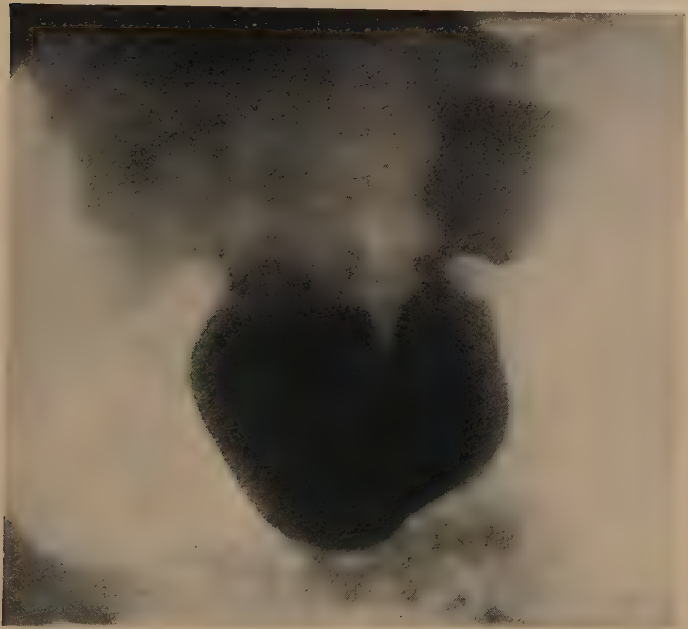

FIG. 94.—Radiogram of an Hour Glass Stomach. The presence of a projection on the lesser curvature opposite the constriction indicates a small ulcer in that position.

lesser omentum and everting the posterior surface of the stomach through the opening thus made.

The **Arterial Supply** of the stomach is derived, either directly or indirectly, from the *cœliac* (*axis*) *artery*, which arises from the aorta just above the neck of the pancreas and at once divides into (1) the left gastric, (2) the splenic, and (3) the hepatic arteries.

1. The **left gastric** (**coronary**) **artery** passes upwards behind the omental bursa to the œsophageal opening in the diaphragm. There it comes into contact with the cardia, and having given off one or two ascending branches to the œsophagus, it descends along the lesser curvature from left to right. It usually divides into two parallel branches, which anastomose with the right gastric (pyloric) artery.

2. The **hepatic artery** runs to the right along the upper border of the pancreas, turns forwards round the right border of the omental bursa just below the epiploic foramen, and reaches the first part of the duodenum. It then turns upwards and ascends between the two layers of the lesser omentum to the liver, in close relation to the bile-duct and portal vein (p. 318).

As the hepatic artery passes round the right border of the omental bursa, it gives off the *right gastric*, which runs to the left along the lesser curvature and anastomoses with the left gastric.

The *gastro-duodenal* artery arises from the hepatic at the upper border of the first part of the duodenum. It descends behind the duodenum to its lower border and there divides into the *superior pancreatico-duodenal* (p. 326) and the *right gastro-epiploic arteries*. The latter passes to the left along the greater curvature of the stomach and anastomoses with the left gastro-epiploic.

3. The **splenic artery** runs to the left behind the omental bursa. It has a tortuous course along the upper border of the pancreas and gives off numerous branches to that viscus. On the anterior surface of the left kidney it turns forwards between the two layers of the lieno-renal ligament and ends in the spleen.

The *short gastric* and the *left gastro-epiploic* arise from the splenic near its termination and run forwards in the gastro-splenic ligament to the greater curvature. The short gastric arteries are distributed to the fundus; the left gastro-epiploic passes to the right along the greater curvature and anastomoses with the right gastro-epiploic.

The stomach, therefore, is supplied directly from the cœliac artery by the left gastric (coronary), and indirectly by the right gastric and gastro-epiploic arteries from the hepatic, and the short gastric and left gastro-epiploic arteries from the splenic (Fig. 95). The branches which these vessels give off supply the adjoining areas on both surfaces of the stomach and run at right angles to its axis. Incisions in the stomach wall, for the purpose of excising gastric ulcers, are made parallel to the vessels and, therefore, at right angles to the long axis of the stomach.

The *gastro-epiploic arteries* lie between the two anterior layers of the greater omentum. They are distinctly tortuous and are placed about half an inch from the greater curvature. By this arrangement the vessels are not subjected to pressure or stretching when the stomach becomes distended.

The **Veins of the Stomach** correspond to the arteries and terminate in the portal vein, or in the two large vessels which form it, viz. the superior mesenteric and the splenic. At the cardia, the coronary vein anastomoses freely with the œsophageal veins through the œsophageal opening in the diaphragm. In this situation, therefore, an important communication occurs between the portal and systemic circulations, and the veins at the inferior end of the œsophagus consequently become enlarged and varicose in portal obstruction. Their rupture gives rise to hæmatemesis, which may be the first sign of the condition.

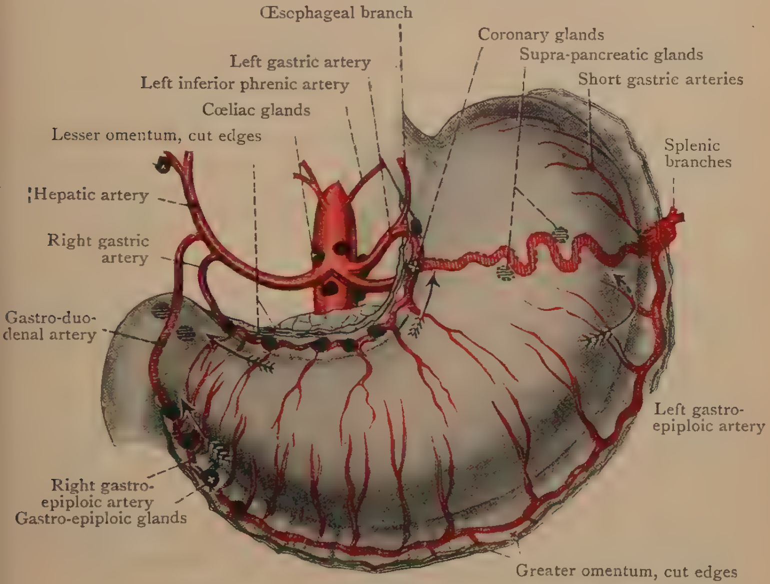
Œsophageal branch
Coronary glands
Supra-pancreatic glands
Left gastric artery
Left inferior phrenic artery
Short gastric arteries
Cœliac glands
Lesser omentum, cut edges
Splenic branches
Hepatic artery
Right gastric artery
Gastro-duodenal artery
Left gastro-epiploic artery
Right gastro-epiploic artery
Gastro-epiploic glands
Greater omentum, cut edges

FIG. 95.—The Arteries and Lymph Glands of the Stomach. The course of the lymph vessels is indicated by the arrows.

The **Nerve-supply of the Stomach** is derived from both vagi, and from sympathetic fibres which are associated with the arteries and derived from the cœliac plexus. The sympathetic nerves leave the spinal medulla in the mid-thoracic region (T. 5-8). Referred pain frequently occurs in connection with gastric disorders, and its site is most commonly the epigastrium. The afferent impulses from the viscus are such that a "focus of irritation" (Mackenzie) may be established in the mid-thoracic region of the spinal medulla. As a result stimulation of the terminal fibres of the afferent nerves which are connected with the segment or segments involved produces an abnormal response. In this way, localised hyperæsthetic or hyperalgesic areas of skin and muscle may be explained. As the proximal part of the stomach is supplied by the nerves which arise from the higher segments of the spinal medulla, the situation of these areas on the surface of the body should give an indication of the site of the gastric lesion. Thus a hyperæsthetic area due to an ulcer near the cardia should be in the upper part of the epigastric region (T. 6, Fig. 72), whereas a similar area due to a lesion near the pylorus should be in the lower part of the same region (T. 8).

In the examination of patients suffering from gastric disorders, the areas supplied by the posterior rami of the 5th-8th Th. nerves should also be tested, as hyperæsthesia and hyperalgesia of the skin of the back and the underlying sacro-spinalis muscle are frequently present.

Examples of the viscero-motor reflex (p. 255) are also commonly found in gastric mischief. They give rise to localised areas of contraction in the upper parts of both recti (more especially the left), and also in the sacro-spinalis.

The **Lymph Vessels of the Stomach** anastomose freely with one another in its walls, but the lymph-flow passes in different directions from three areas, which may be roughly indicated in the following way. A line is drawn from the highest point on the fundus downwards and to the right to the pylorus so as to divide the organ into an upper, larger, and a lower, smaller area. The latter is again subdivided by a line drawn upwards from the middle of the greater curvature.

The *primary lymph glands* of the upper area are (1) the coronary group, and (2) the supra-pyloric lymph gland. The *coronary group* lies between the two layers of the lesser omentum, and is closely associated with the left gastric vessels, while the lymph stream flows in the same direction as the coronary vein as far as the cœliac artery. The *supra-pyloric lymph gland* lies immediately above the pylorus in association with the right gastric vessels, and the lymph stream in this small area follows the course of the hepatic artery. From both the efferents pass to the *cœliac lymph glands*, which therefore constitute the *secondary* or *main group* for the upper area of the stomach. They lie around the trunk of the cœliac (axis) artery and belong to the pre-aortic group (Fig. 95).

The *primary lymph glands* of the right lower area lie between the two anterior layers of the greater omentum in relation to the right gastro-epiploic vessels. They form the inferior gastric chain, and those near the pylorus are termed the *sub- and retro-pyloric glands*. Their efferents accompany the gastro-duodenal and hepatic arteries and end in the cœliac group.

The *primary lymph glands of the left lower area* lie along the upper border of the body and tail of the pancreas. Their afferents from the stomach reach them by passing through the gastro-splenic ligament; their efferents terminate in the cœliac group.

The direction of the lymph flow from the three areas described above is of great practical importance in connection with malignant disease of the stomach. This condition usually begins near the pylorus and spreads upwards along the lesser curvature in the direction of the lymph flow. Its removal therefore necessitates the excision of as much of the lesser curvature as possible, and a not inconsiderable portion of the greater curvature as well.

Owing to the direction of the lymph stream, the disease rarely spreads to the duodenum, and therefore only its first inch or so requires to be removed. In addition, the coronary, supra-pyloric, and inferior gastric lymph glands must be taken away in order to minimise the chances of recurrence.

Pylorectomy.—The feasibility of pylorectomy or partial gastrectomy having been recognised, the first step in the operation consists of the division of the lesser omentum near the liver. It is then stripped away with gauze in a downward direction, care being taken to avoid injury to the important structures in its right free margin. The first part of the duodenum is separated from the portal vein and the head of the pancreas (Fig. 87), and rendered freely movable. At the same time the gastro-duodenal (or right gastro-epiploic) and the right gastric vessels are exposed, ligatured, and divided. The duodenum is then cut through between two clamps, about 1 or 1½ inches beyond the pylorus, and its distal stump is invaginated. Next, the stomach is drawn downwards and to the left, and the left gastric vessels are ligatured close to the cardia. The lower blade of a clamp is now passed through the greater omentum below the gastro-epiploic vessels and carried upwards through the omental bursa behind the stomach. The superficial blade follows anteriorly, and the clamp is then fixed in such a way as to remove as much of the lesser curvature and as little of the greater as may be necessary. After ligature of the left gastro-epiploic vessels, the area thus mapped out is removed along with its associated lymph glands. The proximal cut surface of the stomach is closed, and a posterior gastro-enterostomy completes the operation.

In the course of *malignant disease of the lesser curvature*, the cœliac lymph glands are involved secondarily to the coronary and supra-pyloric, and the infection may be carried down into the pelvis by retro-peritoneal lymph vessels. Secondary deposits frequently occur in the liver. They may be due to the primary growth ulcerating into the gastric veins and the passage of cancerous emboli along the portal vein; or the spread may be by the lymph vessels. In this case the coronary lymph glands become obstructed by the disease, and, as a result, stasis, or a reversal of the direction of the flow, occurs in the lymph vessels which they receive from the liver.

If cancer cells pass along the efferents of the cœliac lymph glands and enter the thoracic duct, they may subsequently infect the left lower anterior group of the deep cervical lymph glands (p. 137), which are sometimes found enlarged in malignant disease of the stomach. From the thoracic duct the cells may pass into the left innominate vein and so be deposited in any part of the body.

Gastro-Enterostomy.—When the stomach fails to empty itself efficiently owing to pyloric obstruction, atony, or for any mechanical reason, the condition may be improved by the operation of gastro-enterostomy, with or without additional complete closure of the duodenum. In the presence of gastric or duodenal ulceration associated with hyperchlorhydria, the same operation may be performed to provide a new outlet from the stomach, thus giving to the ulcer the necessary rest from irritation; at the same time it permits the bile to enter the stomach and neutralise the hyperacid gastric contents.

The operation of choice is the method known as "Posterior, no-loop, antiperistaltic gastro-jejunostomy." When the abdomen has been opened, preferably in the median plane, the duodeno-jejunal flexure and the first few inches of the jejunum must be identified. The greater omentum and transverse colon are drawn out of the abdomen with the left hand, until the transverse meso-colon is rendered tense, and the latter is then traced backwards to its attachment with the right hand. On the left side of the vertebral column and immediately below the transverse meso-colon the fingers encounter the first coil of the jejunum; this is withdrawn through the wound, and in the process the duodeno-jejunal flexure is recognised by its fixation. The surgeon then makes an opening in the greater omentum below the gastro-epiploic vessels, and, passing his left hand into the omental bursa, holds the transverse meso-colon tense. With his right hand he then divides the latter fold for at least two inches in a vertical direction. Through this opening, which is made to the left of the middle colic artery (p. 340), the surgeon passes the proximal piece of the jejunum into the omental bursa with his right hand. Maintaining the gut in its original direction, he draws it out with his left hand through the opening in the greater omentum (Stiles). A long intestinal clamp is applied along the extended loop of bowel, after it has been emptied by massage. At this stage the transverse colon and greater omentum are replaced in the abdominal cavity and the postero-inferior surface of the stomach is turned out through the opening in the latter. The site for anastomosis is selected, preferably the most dependent part of the greater curvature, and a second clamp is applied transversely to this area of the stomach. The anastomosis is carried out, and finally allowed to drop back into the omental bursa. After the opening in the greater omentum has been closed, the transverse colon is again lifted out of the abdomen and the jejunum is lightly drawn upon until the anastomosis appears at the opening in the transverse meso-colon. The margins of this opening are stitched to the posterior wall of the stomach or to the jejunum. This hinders the latter from being retracted through the opening and prevents the occurrence of hernia of small intestine into the omental bursa.

It is important to remember that during this or any other intestinal anastomosis the hæmorrhage from the wounded bowel is controlled by those sutures which pierce all three coats; they must therefore be kept taut until the suturing is completed. The reasons for the choice of the method described above may be briefly stated as follows:

1. The posterior anastomosis is preferable because, in the conditions for which the operation is performed, the most dependent part of the stomach is on the postero-inferior surface near the greater curvature.

2. The union of the proximal part of the jejunum to the

stomach without any loop is very rarely followed by the formation of kinks or spurs.

3. The original direction and position of the first coil of the jejunum, which is directed towards the left, are preserved ; the anastomosis is therefore antiperistaltic.

4. The anastomosis is carried out through an opening in the greater omentum. While it is being established, all the viscera except those parts immediately concerned in the suturing are within the abdominal cavity. Thus the more movable jejunum is approximated to the less movable stomach (Stiles).

5. Both the hands of the assistant are left free.

It may sometimes be found impossible to perform the posterior operation if adhesions, which may obliterate the omental bursa, render the stomach less freely movable or if the transverse meso-colon is too short. Under these circumstances the anterior method of anastomosis is adopted.

Anterior Gastro-Enterostomy.—This route necessitates the use of a loop, as it is impossible to bring the proximal end of the jejunum into contact with the anterior surface of the stomach in a satisfactory manner. The duodeno-jejunal flexure is found and the gut is traced distally for eighteen or twenty inches. A loop of jejunum is then brought upwards in front of the greater omentum and sutured to the anterior surface of the stomach near the greater curvature. The loop is intentionally made longer than is necessary, in order to guard against subsequent obstruction, because, as a general rule, the patient puts on weight after this operation, and much fat may be deposited in the greater omentum.

Occasionally in loop operations a kink or spur may form and obstruct the outlet into the distal limb of the anastomosis. The bile collects in the proximal limb and together with the food is prevented from passing onwards. If the pylorus is patent, this may set up a vicious circle. It is therefore usual to carry out entero-anastomosis in addition to the loop operations, and the jejunum on the proximal side of the gastro-enterostomy is joined to the jejunum on the distal side. This allows the bile to short-circuit into the small intestine at some distance from the gastric anastomosis.

After this second step, *peptic ulceration* occasionally occurs in those portions of the jejunum between the gastric anastomosis and the entero-anastomosis, since in this area the hyperacid chyme is not neutralised by the alkaline bile.

Development of the Stomach and the Omental Bursa (Lesser Sac).—The first indication of the stomach is a fusiform dilatation, which appears in the caudal part of the foregut during the fourth week. It is median in position and is moored to the anterior and posterior abdominal walls by a ventral and a dorsal mesentery. The dorsal aspect of the stomach grows more rapidly than the ventral, and the lower or pyloric end is first thrust forwards and is then rotated to the right side. In this way what was originally the left surface of the stomach now becomes anterior, and it carries the left vagus nerve with it. The rotation of the stomach produces a fossa between it and the dorsal wall; this is the site of the omental bursa.

The lower part of the dorsal mesentery of the stomach grows rapidly and sags downwards into the abdomen, converting the fossa into a bursal sac which has a widely open mouth looking to the right. At the same time the mesentery of the duodenum shortens and then disappears, so that the lower margin of the epiploic foramen becomes defined.

The *spleen* develops as a condensation of the mesoderm between the two layers of the dorsal mesentery in its upper part and divides it into the gastro-splenic and lieno-renal ligaments.

The **Duodenum** extends from the pylorus to the duodeno-jejunal flexure. It forms a C-shaped bend, which encloses the head of the pancreas, and its total length is about ten inches.

When the body is in the supine position, the **Superior** or **First Part** of the duodenum passes backwards and slightly upwards from the pylorus to the neck of the gall-bladder, and is in relation to the inferior surface of the liver. When the body is in the erect position, this part passes vertically upwards owing to the descent of the pylorus (p. 294), and the level of the first flexure of the duodenum sinks downwards, sometimes, to the second lumbar vertebra. The *proximal inch* or less of the first part is freely movable, as it is invested by the same two layers of peritoneum as enclose the stomach. Its upper border is related to the lesser omentum and the right gastric (pyloric) artery, and its lower border to the greater omentum and the right gastro-epiploic artery. Behind it lies a small recess of the omental bursa. The *distal inch* or more of this part receives from the peritoneum only an anterior covering so that its range of movement depends entirely on the elasticity or looseness of its peritoneal coat. Its posterior, or postero-medial, surface is in immediate relation to the bile-duct, portal vein, and gastro-duodenal artery, while the inferior vena cava is separated from it by these structures and by some areolar tissue (Fig. 87).

The whole of the antero-lateral surface of the first part of the duodenum lies in the supra-colic subdivision of the peritoneal cavity. This aspect is the commonest site of duodenal ulceration, and perforation will primarily infect the supra-colic compartment. On the other hand, perforation of an ulcer on the postero-medial surface will, if it is situated close to the pylorus, at once involve the omental bursa; but if it is placed more distally, the infection will be retroperitoneal and may pass up along the inferior vena cava to the extra-peritoneal subphrenic area (p. 313).

As the closure of such perforations results in marked narrowing of the lumen of the gut, gastro-enterostomy is usually performed lest complete obstruction should follow.

Mayo has suggested that the frequency with which *duodenal ulcer* occurs on the antero-lateral wall is determined by the fact that the over-acid chyme, as it is squirted through the pylorus, incessantly impinges on this wall and produces repeated minute traumata. It has also been urged that the area in question is supplied by a small branch from the hepatic or gastro-duodenal, and that its terminal twigs are end-arteries, *i.e.* do not anastomose with other vessels in the neighbourhood. Thrombosis in this artery, therefore, would in all probability give rise to necrosis of the area supplied by it. In childhood, however, the anastomosis is complete.

The **Descending** or **Second Portion** passes downwards from the neck of the gall-bladder along the medial border of the right kidney to the level of the third lumbar vertebra, lying in front of the hilum of the kidney and the commencement of the ureter. It is crossed anteriorly, in its lower part, by the transverse colon, which at this point may or may not possess a mesentery, and in this situation the peritoneum, which gives it an anterior covering only, is lifted from its surface. Above the transverse colon, the second part of the duodenum lies in the supra-colic compartment; below, it lies in the right infra-colic compartment and is related laterally to the ascending colon (Fig. 88). The head of the pancreas and the terminal part of the bile-duct are related to its medial side.

Owing to its peritoneal relations, the second part of the duodenum is fixed in position. In *retro-peritoneal exploration f the lower end of the bile-duct* (p. 319) it must be rendered movable so that it can be turned downwards, forwards, and to the left. This can be effected by incising the peritoneum over the right kidney along the lateral border of the upper end of the second part of the duodenum (Kocher).

If necessary, this incision may be extended downwards along the lateral margin of the right colic flexure and the ascending colon. The duodenum and the ascending colon can then be lifted off the right kidney and turned to the left

(Fig. 96). In freeing the duodenum, the right renal vessels are exposed as they lie in close relation to its posterior surface (see also p. 319).

The **Horizontal** or **Third Part** of the duodenum runs transversely to the left in front of the ureter, the inferior vena cava, and the aorta to end at the left side of the third lumbar vertebra. It lies behind the peritoneum in the right infra-colic compartment, but at its termination it is crossed by the root of the mesentery. The superior mesenteric vessels and accom-

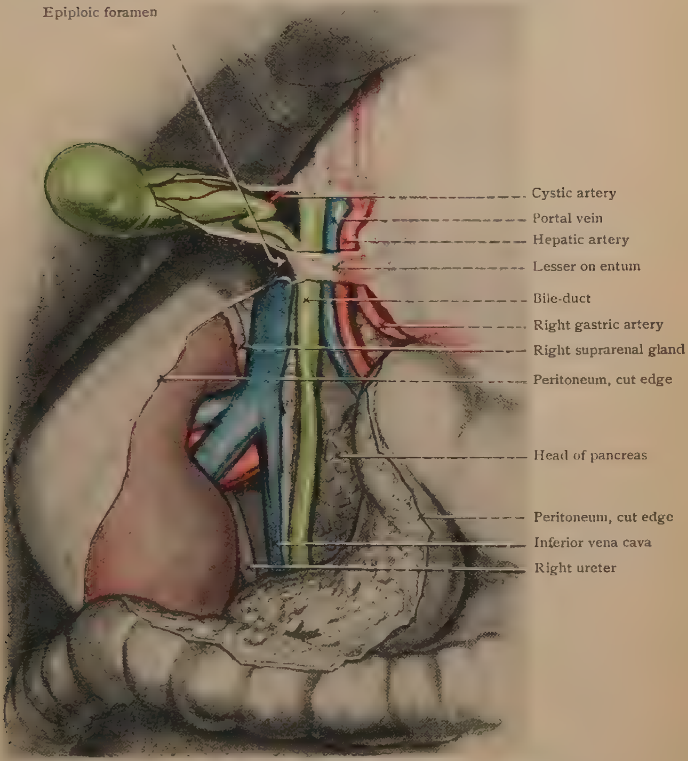
Epiploic foramen
Cystic artery
Portal vein
Hepatic artery
Lesser omentum
Bile-duct
Right gastric artery
Right suprarenal gland
Peritoneum, cut edge
Head of pancreas
Peritoneum, cut edge
Inferior vena cava
Right ureter

FIG. 96.—Exposure of the Terminal Part of the Bile-Duct. The peritoneum has been incised along the right sides of the right colic flexure and of the duodenum. The duodenum and the flexure have been turned downwards and to the left, exposing the posterior surface of the head of the pancreas. A small window has been made in the anterior layer of the lesser omentum at its right border.

panying nerves run downwards over its anterior surface and enter the root of the mesentery (Fig. 88). This relationship is of great importance in the condition of enteroptosis. The weight of the small intestine, hanging down into the pelvis, stretches the superior mesenteric artery tightly across the third part of the duodenum, producing obstruction which may lead to acute dilatation of the stomach.

The head of the pancreas lies in contact with the upper border of this part of the duodenum; in the groove between these two structures the inferior pancreatico-duodenal artery (p. 326) runs towards the right.

The **Ascending** or **Fourth Part** of the duodenum runs upwards, and slightly to the left, to the duodeno-jejunal flexure. Its left side is covered by the peritoneum on the posterior wall of the left infra-colic compartment, while its right side is in contact with the pancreas and the aorta.

At the left side of the second lumbar vertebra the fourth part of the duodenum bends sharply forwards, downwards, and to the left to form the **Duodeno-Jejunal Flexure.** This bend lies in contact with the inferior surface of the pancreas immediately below the root of the transverse meso-colon. It can be found by passing the hand backwards behind the greater omentum to the posterior abdominal wall, and then carrying it upwards along the left side of the vertebral column until the fingers are caught in the loop of the flexure (see also p. 305).

Duodenal Peritoneal Fossæ.—In the region of the duodeno-jejunal flexure there are several inconstant fossæ which require description, as they may be responsible for strangulated retro-peritoneal herniæ.

1. The *superior duodenal fossa* is bounded in front by a free crescentic margin, which extends to the left for about one inch from the duodeno-jejunal flexure. Its mouth looks downwards, while its cavity passes upwards towards the pancreas. The upper part of the inferior mesenteric vein may lie along its lateral border and project into its anterior wall.

2. The *inferior duodenal fossa* is at a lower level and its mouth looks upwards. Its anterior margin is about one inch long and is attached medially to the fourth part of the duodenum.

3. The *paraduodenal fossa,* when present, is larger than the others. Its mouth looks medially, and its free crescentic margin, which may be two inches long, may unite the lateral extremities of the free borders of the superior and inferior fossæ when they are also present. The inferior mesenteric vein runs upwards in its anterior wall, and the ascending branch of the left colic artery (p. 343) may occupy a similar position or may lie along its lateral margin. When a hernia enters this fossa it carries its sac downwards and laterally behind the posterior parietal peritoneum and the vessels already mentioned, but in front of the left ureter or kidney. Should strangulation occur, great care must be taken in dividing the neck of the sac lest the inferior mesenteric

vein or the left colic artery be injured; the neck of the sac should be incised in a downward direction, parallel to the vessels.

4. The *duodeno-jejunal fossa* is bounded by a fold which extends from the flexure to the left, and its mouth is directed upwards and forwards towards the transverse meso-colon.

Surface Marking of the Duodenum.—The duodenum can now be mapped out on the surface. The first flexure lies a little above the transpyloric plane at a distance of 1½-2 inches from the middle line. The second portion descends medial to the right lateral line and extends a little below the subcostal plane. The third portion crosses the middle line horizontally, and the fourth ascends to the duodeno-jejunal flexure, which just reaches the transpyloric plane, one inch to the left of the middle line.

The **Liver** occupies most of the right hypochondriac and epigastric regions. It is roughly pyramidal in shape, its base being directed to the right and its apex lying behind the fifth left intercostal space, half an inch medial to the left lateral line.

The **Anterior Surface** of the liver is related to both halves of the diaphragm, and in the middle line it lies in direct contact with the anterior abdominal wall, occupying the upper part of the subcostal angle (Fig. 97). In this region it can readily be examined by palpation and percussion. It is partially overlapped by the right lung and pleura and, under cover of the left costal margin, by the left pleura and, to a slight extent, by the pericardium (Fig. 97). Its *upper border* can be mapped out by a line drawn from a point on the fifth right rib half an inch medial to the right lateral line, to a second point in the fifth left interspace half an inch medial to the left lateral line. This line curves downwards slightly at its centre and crosses the median plane at the xiphi-sternal junction. The *inferior border* of the anterior surface of the liver extends upwards from the tip of the tenth right to the tip of the eighth left costal cartilage, crossing the middle line at the transpyloric plane, and then ascends to join the upper border. The *right border* of this surface can be indicated by joining the right extremities of the superior and inferior borders by means of a line which is gently convex to the right.

Tropical abscess of the liver may point on the anterior surface, and can then be exposed by an oblique incision just below the right costal margin. If necessary, portions of the eighth and ninth costal cartilages may be resected, but the seventh must be left *in situ* on account of the danger of opening into the right pleural sac (Fig. 97).

The **Right Lateral Surface** of the liver lies under cover of the seventh, eighth, ninth, tenth, and eleventh ribs, and extends a little below the costal margin in the mid-axillary line. It lies in contact with the diaphragm, and is overlapped by the right pleura in rather more than its upper two-thirds (Fig. 151). It is entirely covered by peritoneum, and a recess of the greater sac extends upwards between it and the diaphragm.

Solitary abscess of the liver is commonly situated near the upper surface of the right lobe, and as it enlarges it displaces the diaphragm in an upward direction. Evacuation of a liver abscess is carried out from the right side by means of a curved incision, convex downwards, which is planned so as to expose the eighth and ninth ribs and the adjoining intercostal spaces. The flap, which consists of skin and fasciæ, is turned upwards, and a portion of one or both of the ribs exposed is resected subperiosteally. The periosteum and the costal pleura on its

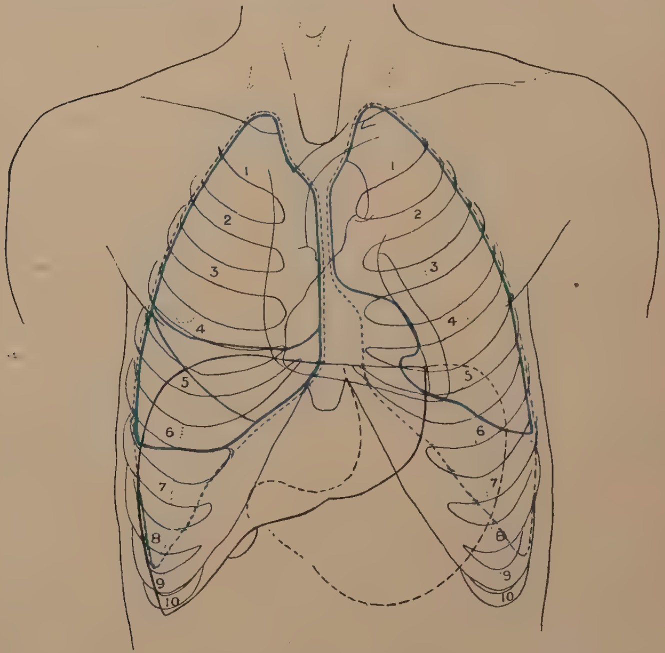

FIG. 97.—Surface Relations of the Liver, Stomach, Lungs, Heart and Pleural Sacs.

Blue line = outline of lung. Dotted blue line = lines of pleural reflection. Fine black line = heart and great vessels. Heavy black line = liver. Dotted black line = stomach.

deep surface are then incised. Usually the pleural sac in this situation is found obliterated by adhesions, but if not, the cavity must be shut off by suturing the upper cut margin of the costal pleura to the diaphragmatic pleura. It will probably be necessary to ligature the intercostal vessels of the space below the rib excised. An incision is then made through the diaphragm into the liver, to which it is generally firmly adherent. The adhesions, which are due to perihepatitis, entirely obliterate the peritoneal recess, which separates the liver from the diaphragm. Sinus forceps can now be thrust through the liver substance into the abscess cavity. A drainage tube may be inserted and brought to the surface through a stab wound in the flap, so that the original incision can be closed.

The **Superior Surface** of the liver is in contact with the diaphragm, and both are covered by peritoneum. It is related above to both lungs and pleural sacs, and to the heart and pericardium.

When a liver abscess ruptures spontaneously it usually does so through the superior surface, after it has become adherent to the diaphragm. It thus enters the pleural sac and gives rise to an empyæma. It sometimes happens that adhesions have fixed the basal surface of the lung to the diaphragmatic pleura, and in these cases the pus ruptures into the lung, being subsequently evacuated by coughing.

The **Posterior Surface** of the liver is in contact with the inferior vena cava and the diaphragm, and lies in front of the lower thoracic vertebræ. The peritoneum on the superior surface is not continued over the posterior surface, but is reflected on to the diaphragm, forming the upper or anterior layer of the coronary ligament. Since the peritoneum on the inferior surface of the right lobe is reflected on to the kidney as the hepato-renal (posterior layer of coronary) ligament, the right half of the posterior surface is devoid of any peritoneal covering. It is known as the "bare area" and is in direct contact with the diaphragm. The bare area of the liver is the site of extra-peritoneal subphrenic abscesses, which result from the upward spread of pus from retro-peritoneal abscesses on the right side of the abdomen.

The **Inferior Surface** of the liver is divided into a large right and a smaller left lobe by the *fossa for the umbilical vein*, which extends from the inferior border of the liver to the left extremity of the *porta hepatis* (*transverse fissure*). The porta is placed transversely on the inferior surface, and its margins receive the attachment of the lesser omentum. From its right extremity the *fossa for the gall-bladder* extends forwards to the inferior border of the liver. In this way a rectangular area is defined, which lies in contact with the pylorus and the commencement of the duodenum.

The inferior surface of the left lobe is related to the antero-superior surface of the stomach. The right lobe is related to the right kidney posteriorly, to the right colic flexure anteriorly, and to the gall-bladder and the duodenum medially.

Tropical abscess of the liver occasionally points on the inferior surface, and may rupture into the right colic flexure.

Blood-vessels of the Liver.—The liver receives its blood-supply from both the *hepatic artery* (p. 300) and the *portal vein*, and after circulating through the liver the blood is returned to the inferior vena cava by the *hepatic veins*.

The **Portal Vein** brings to the liver the blood which has already passed through the capillaries of (1) the whole abdominal alimentary canal, except the lower end of the rectum and the anal canal, (2) the spleen, (3) the pancreas, and (4) the gall-bladder. *Portal obstruction*, therefore, whether due to direct pressure on the portal vein or its branches, or to backward pressure from the heart, will produce venous congestion in all these organs, with enlargement of the spleen and gastro-intestinal disturbance. Serum transudation occurs (1) into the stomach, giving rise to the morning sickness of alcoholic cirrhosis; (2) into the intestines, causing diarrhœa; and (3) into the peritoneal cavity, giving rise to ascites.

Certain channels of anastomosis exist between the portal and the systemic circulation. (1) At the lower end of the œsophagus, the left gastric veins communicate with the œsophageal veins. In portal obstruction these veins become varicose and may rupture, causing hæmatemesis. (2) At the lower end of the rectum the superior, middle, and inferior hæmorrhoidal veins communicate freely. They become varicose in portal obstruction and give rise to internal hæmorrhoids, which may act as a "safety valve" to the venous congestion. In cases of internal hæmorrhoids the possibility of portal obstruction must be excluded before operation is advised. (3) The connections of the para-umbilical vein have been discussed on p. 247. (4) The lumbar veins on the posterior abdominal wall communicate with the mesenteric veins. (5) The veins on the "bare area" of the liver communicate with those on the inferior surface of the diaphragm.

These natural routes seldom suffice to establish compensation, and the *Talma-Morison operation* aims at the production of artificial anastomoses between the portal and the systemic veins. The opposing peritoneal surfaces of the liver, spleen (portal circulation), diaphragm, and anterior abdominal wall (systemic circulation) are greatly irritated to encourage the formation of adhesions. In addition, the greater omentum (portal circulation) may be sutured to the peritoneum of the anterior abdominal wall (systemic circulation).

Development of the Liver.—The liver is developed from a hollow bud which grows upwards from the duodenum into the septum transversum, which, at this period, is represented by a mass of undifferentiated mesoderm, occupying the interval between the stomach and the pericardium. The bud subdivides into two, of which one forms the gall-bladder and cystic duct and the other gives rise to the liver substance. The liver grows with great rapidity and part of the mesoderm of the septum transversum becomes incorporated to form its fibrous stroma. The proximal end of the original outgrowth remains as the bile-duct and retains its connection with the duodenum. The remainder of the septum transversum forms the central portion of the diaphragm, the falciform ligament and the lesser omentum.

The **Gall-Bladder** lies in a fossa on the inferior surface of the right lobe of the liver. It is covered on its inferior surface by peritoneum which binds it closely to the liver, but its fundus may project beyond the lower margin of that organ and it then receives a complete investment. The long axis of the gall-bladder is directed upwards, backwards, and medially towards the porta (hilum) of the liver, where it becomes narrowed to form the cystic duct. On its medial side and inferiorly lie the first part and the commencement of the second part of the duodenum; below and to its lateral side it is in relation to the right colic flexure and the commencement of the transverse colon. After prolonged cholecystitis, it may be united to these viscera by dense adhesions, and occasionally gall-stones may ulcerate through its wall and be discharged into the intestinal canal.

The *cystic artery* arises from the right terminal branch of the hepatic and runs to the right, crossing in front of the common hepatic duct. It divides into a superficial branch which supplies the inferior surface of the gall-bladder, and a deep branch which ramifies between its upper surface and the liver. The *cystic vein* joins the vena portæ

Cholecystectomy.—Ligation of the cystic artery and duct constitutes the first step in cholecystectomy. This is carried out close to the origin of the vessel in order to prevent the hæmorrhage which would otherwise occur when the gall-bladder is stripped from its bed. The peritoneum is then incised along the inferior surface of the gall-bladder and separated from it. After the viscus has been freed from the liver and excised, the cut edges of the peritoneum are united over the exposed area of liver substance.

Pancreatitis may accompany or follow cholecystitis, and produce jaundice by pressure on the bile-duct. On this account the gall-bladder is retained if at all possible, for cholecyst-enterostomy may subsequently be necessary in order to relieve the condition.

The **Nerve-Supply of the Gall-Bladder** is derived from (*1*) the right phrenic (C. 3, 4, and 5), (*2*) the vagus, and (*3*) the cœliac sympathetic plexus (Th. 7-9). The repeated attempts of the gall-bladder to expel calculi into the cystic duct give rise to referred pain, which is commonly felt in the right half of the epigastrium, but severe pain is sometimes experienced over the right shoulder or in the posterior cervical region. In both the latter cases the afferent stimulus does not pass *via* the sympathetic but by the phrenic nerve. The viscero-motor reflex is frequently present in the upper part of the right rectus. These attacks of *biliary colic* cease when the stone has accomplished its journey along the bile-duct into the duodenum, or when the expulsive efforts fail and the stone falls back again into the gall-bladder.

As the centres for the stomach and the gall-bladder occupy the same segments in the spinal medulla, and since both viscera are supplied by the vagus, the symptoms which are due to viscero-sensory and viscero-motor reflexes are very similar in the two cases. Thus in ulceration of the stomach the stimulation of the gastric terminals of the vagus causes vomiting on the ingestion of food. In diseases of the gall-bladder the afferent impulses along the vagus may set up a "focus of irritation" in the medulla oblongata, so that the simple stimulus of the gastric branches of the same nerve, caused by the ingestion of food into the healthy stomach, may elicit an abnormal response from the irritated centre, and emesis results. Errors in diagnosis, therefore, are not infrequent, and are easily explained in the light of the nerve-supply of the two viscera.

The **Fundus of the Gall-Bladder** may be mapped out on the surface in the angle between the right rectus and the costal margin, with the patient in the supine condition. When the gall-bladder becomes distended it enlarges downwards and medially, giving rise to a movable tumour, which may be mistaken for a floating kidney. Owing to its peritoneal connection to the liver, the tumour always returns to its first position after being displaced by manipulations, and this feature should suffice to determine the diagnosis.

The *mucous membrane* lining its interior is so rich in mucus-secreting glands that, when the cystic duct is obstructed by an impacted calculus, the gall-bladder may become dilated and form a *mucocele*. This obstruction offers no hindrance to the free passage of bile into the duodenum, and therefore cholecystitis may be present without an associated jaundice.

In the event of permanent occlusion of the bile-duct from pancreatitis, malignant disease, or stricture, the intense jaundice and the itching which it causes may be relieved by the operation of *cholecyst-enterostomy*. If possible the duodenum is utilised, but, failing it, good results follow the anastomosis of the gall-bladder with the stomach, right colic flexure, or the transverse colon. The operation is carried out on the same lines as gastro-enterostomy or entero-anastomosis.

The **Cystic Duct** is about 1½ inches long, but as it is folded upon itself in an S-shaped manner, its union with the hepatic ducts occurs quite close to the neck of the gall-bladder. The lining mucous membrane is redundant and projects into the lumen as a spiral fold, the *valve of Heister*, which obstructs the passage of a probe except when the duct is greatly enlarged owing to the passage of stones or to intermittent obstruction of the common duct.

The cystic duct may be examined by tracing the gall-bladder upwards, backwards, and medially to the porta hepatis, where it is associated with one or two lymph glands.

The **Common Hepatic Duct** is a short trunk formed by the union of the right and left hepatic ducts in the porta (hilum) of the liver.

The **Bile-Duct** is formed immediately below the porta of the liver by the union of the cystic with the common hepatic duct. It is three to four inches long and passes downwards (1) in the lesser omentum, (2) behind the first part of the duodenum, and (3) postero-lateral to the head of the pancreas, to terminate by opening into the second part of the duodenum.

The **first** or **supra-duodenal portion of the bile-duct** is about 1½ inches long. It descends in the right border of the lesser omentum, lying in front of the portal vein and to the right side of the hepatic artery. Several lymph glands are closely related to the bile-duct at its commencement and near its termination, and they are apt to become enlarged in septic conditions of the gall-bladder and bile-duct, and in malignant disease of the lesser curvature of the stomach and of the pancreas. When enlarged they may be mistaken for impacted gall-stones.

The surgical approach to the gall-bladder (p. 256) is planned so as to afford sufficient exposure for a thorough examination of the bile-passages as well. After the gall-bladder has been dealt with, the index finger of the left hand is passed along its inferior surface and introduced into the epiploic foramen (of Winslow). If the hepato-colic ligament (p. 283) is present, it must be divided to improve the access. The supra-duodenal portion of the bile-duct may then be palpated between the left forefinger and thumb, and if a stone is detected it should be "milked" back along the cystic duct into the gall-bladder. When the stone is impacted, the duct is hooked forwards to the surface and incised longitudinally to permit of its extraction. Advantage may be taken of this opening to pass a probe upwards to explore the hepatic ducts, and downwards to the ampulla of Vater.

The **second** or **retro-duodenal part of the bile-duct** descends behind the first part of the duodenum, to the right of the portal vein and in front of the inferior vena cava (Fig. 87). Its length, usually about one inch, depends upon the upward extent of the head of the pancreas. In order to examine this part of the bile-duct the finger is again introduced into the epiploic foramen and the thumb is placed on the antero-lateral aspect of the first part of the duodenum. When the two are squeezed together the presence of one or more impacted stones can be recognised. It may be necessary to expose the second part of the bile-duct (p. 308), but the stone can sometimes be manipulated downwards into the duodenum, or upwards into the first part of the bile-duct, or it may even be made to retrace its course along the cystic duct into the gall-bladder.

The **third** or **pancreatic portion of the bile-duct** passes downwards and slightly to the right and terminates by piercing the postero-medial aspect of the second part of the duodenum about its middle. It is about 1¼ inches long and lies in a groove on the postero-lateral aspect of the head of the pancreas, being sometimes embedded in its substance. It is separated from the anterior surface of the inferior vena cava by some fibrous tissue. The superior pancreatico-duodenal artery lies first to the right side of the bile-duct and then crosses in front of its lower end. Very often, however, the artery passes behind the duct, and in these cases may give rise to hæmorrhage when the pancreatic portion is being exposed. In this operation hæmorrhage may also be caused by injury of a vein, which issues from the posterior aspect of the head of the pancreas and runs upwards and medially, along the medial side of the pancreatic part of the bile-duct, to join the portal vein. As the bile-duct enters the wall of the duodenum it is joined, on its left side, by the pancreatic duct, and the two open into a dilatation of the canal—the *ampulla of Vater*—which lies partly within the wall (Fig. 98). The opening from the ampulla into the duodenum is placed on the *duodenal* (*bile*) *papilla*, and is so small that gall-stones, which have passed along the whole length of the cystic and bile-ducts, often become impacted in the ampulla. When this occurs, the pancreatic secretion as well as the bile may be prevented from entering the duodenum, unless a communication exists between the main pancreatic and the accessory duct (p. 320). In addition, septic infection, which commonly exists in the presence of gall-stones, is apt to spread along the pancreatic duct and cause pancreatitis. The bile-duct narrows slightly just before opening into the ampulla of Vater, and stones may become impacted in this situation, but in this case the pancreas is not so likely to be affected.

Considerable variation exists in the method of termination of the pancreatic and bile ducts. (1) The two unite, but the ampulla of Vater is absent. (2) The two open independently into the duodenum, either on the summit of a small papilla or at the bottom of a slight depression. In this case the impaction of a stone in the bile-duct does not produce symptoms of pancreatic obstruction (Fig. 98).

The pancreatic part of the bile-duct may be examined by gently pressing the second part of the duodenum against the right side of the vertebral column, but if the head of the pancreas is enlarged and hard owing to chronic pancreatitis, great difficulty may be experienced in determining whether a stone is present or not. *To expose this part of the duct*, it is necessary to free the second part of the duodenum and turn it forwards and to the left (p. 308). At the same time the head of the pancreas is carefully separated from the inferior vena cava and exposed to view. The bile-duct is then found at the upper border of the first part of the duodenum, traced downwards and freed from the pancreas. At this stage some hæmorrhage may occur from cut branches of the superior pancreatico-duodenal vessels. After removal of the stone, satisfactory drainage of the region can be obtained by bringing out a tube in the right loin through the lumbar triangle (of Petit), lateral to the right kidney, and the displaced viscera may then be returned to their original positions.

When a stone is impacted in the ampulla of Vater, a more direct approach is obtained by the *trans-duodenal route*. A vertical incision is made in the supra-colic portion of the second part of the duodenum, and the stone can then be felt under the mucous coat of the postero-medial wall. The orifice of the duodenal papilla lies under cover of one of the plicæ circulares (valvulæ conniventes), and may sometimes be located by expressing some bile from it.

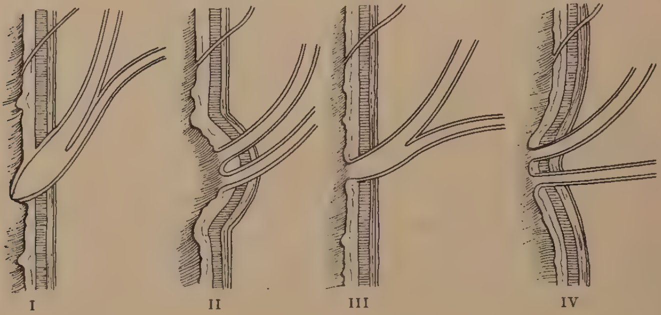

FIG. 98.—Diagrams to show the Varying Modes of Termination of the Bile-Duct and the Pancreatic Duct.

I shows the normal arrangement, with the accessory pancreatic duct opening independently into the duodenum at a higher level.

The exit from the ampulla of Vater is then enlarged by slitting it in an upward direction until it permits of the extraction of the stone.

The bile-duct may be exposed to considerable pressure from the head of the pancreas in malignant disease or in chronic pancreatitis, on account of the intimate relation of the two structures. In the former, the steadily increasing obstruction is accompanied by the gradual onset of jaundice, which slowly but surely increases in intensity; in chronic pancreatitis the colour changes are more irregular. It sometimes happens that a calculus ulcerates from the duct into the gland and constitutes a foreign body in the head of the pancreas, which can only be removed by incising the gland.

The **Pancreas** is an elongated gland, which crosses the posterior abdominal wall from right to left with an upward inclination. It consists of a head, a neck, a body and a tail, and, with the exception of the tail, which usually lies between the two layers of the lieno-renal ligament, it is entirely retroperitoneal.

The **head** lies in the concavity of the duodenum and is covered anteriorly by the pylorus, above, and the transverse colon, below. Posteriorly, it rests upon the inferior vena cava and the right renal vessels, and is grooved by the bile-duct (p. 318).

The **neck** passes upwards and to the left to become continuous with the body. It is covered anteriorly by the peritoneum on the posterior wall of the omental bursa and supports the pyloric end of the stomach. Behind it the superior mesenteric and splenic veins unite to form the portal vein.

The **body** of the pancreas crosses the middle line at or a little below the transpyloric plane. It is somewhat triangular on section and consequently possesses three surfaces. The *anterior surface* is covered by the peritoneum on the posterior wall of the omental bursa (Fig. 85) and forms part of the stomach-bed. The *inferior surface* is covered by the peritoneum of the greater sac and is in relation to both infra-colic compartments and the duodeno-jejunal flexure. These two surfaces are separated from one another by the anterior border of the gland, along which the two layers of the transverse meso-colon separate from one another (Fig. 85). The *posterior surface* crosses in front of the aorta, the left suprarenal gland and the left kidney (Fig. 87), and is partially separated from all of these structures by the splenic vein.

The **tail** of the pancreas usually lies between the two layers of the lieno-renal ligament and is related to the left colic flexure, inferiorly.

The **Pancreatic Duct** commences in the tail and traverses the whole gland near its posterior surface. It emerges from the right border of the head and opens into the ampulla of Vater, together with the bile-duct. An *accessory duct* drains part of the head and opens into the duodenum above the ampulla. It may communicate with the main pancreatic duct, and when it does so it may convey the whole of the pancreatic secretion to the duodenum in the event of obstruction of the terminal part of the main duct (p. 319). When the obstruction is not relieved in this way, retention cysts may arise in the gland.

Cysts of the Pancreas may project (1) from its anterior surface, (2) from its anterior border, or (3) from its inferior surface.

(1) Cysts on the anterior surface of the gland project into the omental bursa. As they enlarge, they may push the lesser omentum forwards and reach the anterior abdominal wall above the lesser curvature; or they may push forwards the upper part of the greater omentum and reach the surface below the greater curvature but above the transverse colon.

(2) Cysts which appear on the anterior border may separate the two layers of the transverse meso-colon and thrust the transverse colon before them to the surface. In this condition the dull percussion note over the tumour is interrupted by the tympanitic note of the transverse colon.

(3) Cysts which appear on the inferior surface of the gland project into the infra-colic compartment and thrust the greater omentum before them. They come into contact with the anterior abdominal wall below the transverse colon.

The **Arterial Supply of the Pancreas** is derived from three sources. (1) The superior pancreatico-duodenal, a branch of the gastro-duodenal (p. 300), and (2) the inferior pancreatico-duodenal, a branch of the superior mesenteric (p. 326), supply the head of the gland. (3) The pancreatic branches of the splenic artery supply the rest of the gland.

The **Veins of the Pancreas** join the splenic vein, but a fairly large vein issues from the dorsal aspect of the head and runs upwards, to the left of the bile-duct, to join the portal vein. This vessel may give rise to hæmorrhage during the exposure of the third part of the bile-duct (p. 319).

Development of the Pancreas.—The pancreas is developed from two hollow buds, of which one springs from the ventral and the other from the dorsal aspect of the duodenum. The *ventral bud* arises at the same point as the liver-bud, but it only forms a small portion of the head of the pancreas, while the *dorsal bud* gives rise to the rest of the head, to the neck, body and tail of the gland. The two masses of cells grow into the mesentery of the duodenum and fuse with one another. Their ducts also unite and, as growth proceeds, the proximal part of the dorsal duct remains small, so that the main adult duct is derived from the ventral duct and the distal part of the dorsal duct, and consequently opens into the ampulla of Vater in common with the bile-duct. Although small, the proximal part of the dorsal duct persists as the accessory pancreatic duct and retains its original connection with the duodenum. The communication of the two primitive ducts with one another may or may not be retained (see p. 319).

The **Spleen** lies in the left hypochondriac region under cover of the ninth, tenth, and eleventh ribs, and its long axis corresponds roughly to the tenth. It is almost completely surrounded by peritoneum and projects into the greater sac between the stomach and the lateral part of the left kidney. It is attached to the greater curvature of the stomach by the gastro-splenic ligament, and to the anterior surface of the left kidney by the lieno-renal ligament (Fig. 87). The postero-lateral aspect of the spleen lies in contact with the diaphragm, and its antero-medial surface is related to the stomach, in front, the kidney, behind, and the left colic flexure and the phrenico-colic ligament, below.

The **diaphragmatic surface** of the spleen is roughly triangular in shape, and its apex or superior angle can be indicated on the dorsal surface of the body at a point 1½ inches lateral to the tenth thoracic spine. Its inferior angle lies opposite the eleventh intercostal space about 3½ inches lateral to the first lumbar spine, and its anterior angle is placed on the mid-axillary line in the ninth intercostal space (Fig. 84). When these points are joined to one another by lines which are slightly convex outwards, the surface outline of the diaphragmatic surface of the spleen is obtained (Stiles). It will be seen from Fig. 99 that the whole of this surface is separated by the diaphragm from the left pleural sac; in addition, in its upper part it is overlapped by the inferior margin of the left lung (p. 297). In puncture of the normal spleen, the needle must pass through the muscular wall, the pleural sac, the diaphragm and the peritoneal cavity before the organ is reached.

The **splenic artery** has already been described (p. 300).

The **splenic vein** issues from the hilum of the spleen and is at once joined by the left gastro-epiploic veins and the venæ breves, which pass from the stomach between the two layers of the gastro-splenic ligament. It then runs backwards in the lieno-renal ligament to the posterior abdominal wall, where it turns to the right behind the pancreas. It receives numerous pancreatic veins, and is joined, near its termination, by the inferior mesenteric vein. Behind the neck of the pancreas it is joined by the superior mesenteric vein, and the two together form the portal vein. Portal obstruction, therefore, invariably gives rise to venous congestion of the spleen (p. 314).

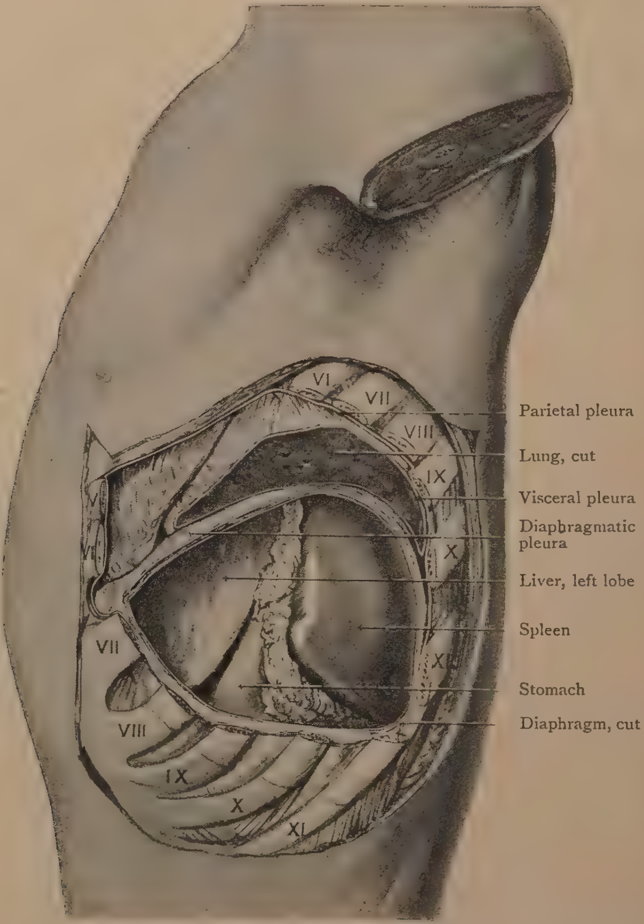
VI
VII
VIII
IX
X
XI
V
VI
VII
VIII
IX
X
XI
Parietal pleura
Lung, cut
Visceral pleura
Diaphragmatic pleura
Liver, left lobe
Spleen
Stomach
Diaphragm, cut

FIG. 99.—Dissection to expose the Spleen. Portions of the 5th-11th ribs have been resected. A part of the lower lobe of the left lung and a part of the left half of the diaphragm have also been removed.

The **lymph vessels** of the spleen terminate in the lymph glands at the hilum. From these splenic glands the afferents pass to the pancreatic and cœliac lymph glands.

Splenic Enlargement.—When the spleen becomes enlarged, in malaria, splenic anæmia and other diseases, its anterior border projects beyond the left costal margin and is in contact with the deep surface of the anterior abdominal wall. Normally this border possesses one or two notches or indentations, and in splenic enlargement the notches become more pronounced. On palpation of a tumour in the left lumbar region, the discovery of one or more notches on its anterior border may settle the diagnosis.

The direction taken by the enlarging spleen is usually obliquely downwards and medially, as the phrenico-colic ligament and the splenic flexure obstruct its enlargement in a purely downward direction.

Splenectomy.—Owing to its vascularity, stab wounds or rupture of the spleen give rise to severe hæmorrhage, and removal of the organ may be necessary. Good access is obtained by an incision similar to that described for operations on the gall-bladder (p. 256), but on the opposite side, or by a long vertical incision through the left rectus. Thereafter, two methods are open to the surgeon. (1) The omental bursa is opened by tearing through the greater omentum just above the transverse colon. The stomach is retracted upwards and the peritoneum is cautiously divided at the upper border of the pancreas. The splenic artery is exposed and the vein is found at a slightly lower level. Both vessels are tied in this situation, and the hæmorrhage is at once reduced. The gastro-splenic ligament may now be ligatured and divided piece by piece. When the lieno-renal ligament has been similarly treated, the spleen can be removed.

(2) The spleen is drawn forwards to the abdominal wound, and the left side of the lieno-renal ligament is exposed. The ligament is ligatured and divided piece by piece. The spleen is then drawn over to the left in order that the same procedure may be carried out with regard to the gastro-splenic ligament.

It may not be possible to carry out the second method if perisplenitis has caused adhesions to form between the spleen and the diaphragm.

Small Intestine.—The freely movable part of the small intestine extends from the duodeno-jejunal flexure to the cæcum. The upper two-fifths constitutes the **jejunum** and the lower three-fifths the **ileum,** but there is no definite line of demarcation. These two parts of the alimentary canal together measure about twenty-three feet, and they are suspended from the posterior abdominal wall by the mesentery, which gives them an almost complete investment of peritoneum. The coils of the jejunum and ileum occupy the infra-colic compartments and the pelvis, and are usually covered over by the greater omentum. In most cases the *first loop of the jejunum* can be found on the anterior surface of the left kidney, near its lower pole, while the *lowest loop of the ileum* lies in the pelvis.

The Mesentery.—The *root of the mesentery* begins on the anterior surface of the fourth part of the duodenum in front of the left side of the second lumbar vertebra, and extends downwards and to the right. It crosses, successively, in front of the third part of the duodenum, the aorta, the inferior vena cava, the right ureter and the psoas major, and terminates in the right iliac fossa at the ileo-cæcal junction. This line of attachment is only six or seven inches in length, and, in order to enclose the twenty-three feet of intestine, the mesentery spreads out in a fan-shaped manner and becomes very much pleated near the gut. Its depth varies, being as much as seven or eight inches at its deepest part. The two peritoneal layers of which it consists contain between them nerves, blood-vessels, lymph vessels (lacteals) and glands, and a varying amount of fat. The latter is more thickly deposited along the root, and it diminishes in quantity as the mesentery is traced to the intestine. This feature is much better marked in the upper than in the lower end of the mesentery, and, when it is examined near the duodeno-jejunal flexure, semi-translucent peritoneal " windows " can be seen, separated from one another by branches of the superior mesenteric artery (Fig. 100). These " windows " become more obscure as the jejunum is traced downwards, and, in the lower part of the ileum, they cannot be distinguished owing to the larger deposition of fat near the gut (Fig. 101). By the examination of the mesentery, therefore, it may be possible to determine whether a loop of small intestine, drawn out through an abdominal wound, belongs to the upper or lower part of the canal. At the same time it is important that the surgeon should be able to distinguish the proximal from the distal end of such a loop. If its mesentery is not twisted in any way—this can be ascertained by tracing it back to the vertebral column—the upper or left end of the loop on the surface is also in reality its proximal end.

A small area, almost devoid of fat and even sieve-like in character, is occasionally found near the lower end of the mesentery (Treves), and may break down, forming a circular opening through which a coil of gut may pass. This internal hernia may wind itself round the ileum and may even pass through the opening a second time, the condition leading to symptoms of acute obstruction. The margins of the opening are thickened, rounded and smooth, and contain an arterial circle formed by the ileo-colic artery, its ileal branch and the lowest intestinal branch of the superior mesenteric artery. The vessels are unusually large, and a single anastomotic artery replaces the arterial arcades along the mesenteric border of the gut.

The **Superior Mesenteric Artery** arises from the aorta behind the pancreas and descends in front of the third part of the duodenum. It then enters the root of the mesentery and runs downwards and to the right at a distance of about half an inch from the posterior abdominal wall.

Close to its origin it gives off the *inferior pancreatico-duodenal* artery, which runs to the right between the head of the pancreas and the duodenum, supplying both these structures and anastomosing with the superior pancreatico-duodenal (p. 300).

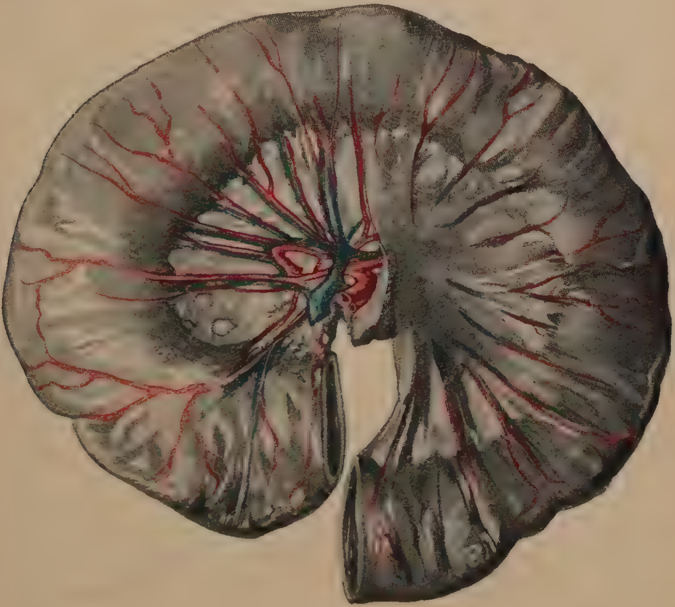

FIG. 100.—A Coil from the upper part of the Jejunum. The peritoneum has been partially removed to show the arterial arcades. Compare the appearance of the "windows" and the disposition of the fat in the mesentery with Fig. 101.

The *intestinal arteries* form a series of twelve to fifteen branches, which arise from the left side of the superior mesenteric and pass towards the jejunum and ileum. They break up into branches which unite and reunite to form a connected series of arcades, which are more complex in the ileum than in the jejunum (Fig. 101). From the terminal arcades, small branches pass to the mesenteric border of the gut and there bifurcate

In the intestinal wall they run parallel to the circular muscular coat, at first in the subserous, then in the muscular, and finally in the submucous coat.

The *ileo-colic* (p. 337), *right colic* (p. 340) and *middle colic arteries* (p. 340) are described in connection with the large intestine.

In dividing the bowel, previous to carrying out an anastomosis, it is advisable to remove less of the mesenteric than of the anti-mesenteric border in order that the retained cut margin may have a good blood-supply.

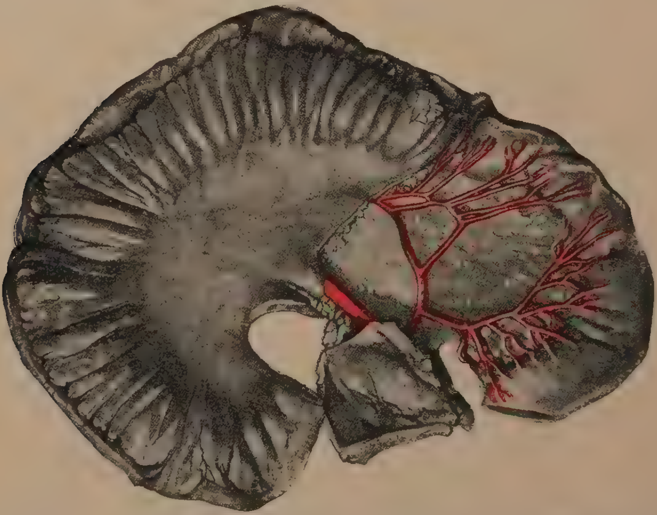

FIG. 101.—A Coil from the lower part of the Ileum. The peritoneum has been partially removed to show the arterial arcades. Observe how the fat in the mesentery overlaps the gut, and compare with Fig. 100.

The **lymph vessels** of the jejunum and ileum join the superior mesenteric lymph glands, which lie between the two layers of the mesentery. This group includes a large number (100 to 200) of glands, and may be directly infected with tuberculosis from the alimentary canal. When they break down they involve one or both of the infra-colic compartments. Their efferents join the pre-aortic glands.

In the walls of the small intestine the lymph vessels run at right angles to the long axis, and when they are infected from the tuberculous ulceration of an *aggregated lymph nodule* (*Peyer's patch*), the spread of the disease along them may produce a stricture of the gut. These lymph nodules are most numerous in the terminal part of the ileum, and it is consequently the commonest site for tuberculous stricture. On this account, too, enlarged glands are frequently found in the region of the colic (ileo-cæcal) valve.

The **nerves of the small intestine** are derived from the aortic sympathetic plexus, and their centres in the spinal medulla lie in the ninth, tenth, and eleventh thoracic segments. *Referred pain* in connection with this part of the alimentary canal is felt in the areas supplied by the ninth, tenth, and eleventh thoracic nerves (Fig. 72), and, clinically, it usually involves the umbilical region, only occasionally spreading to the lumbar region and the back. When an inguinal hernia which contains small intestine becomes strangulated, the pain is at first experienced near the umbilicus and not immediately over the swelling.

Structure of the Small Intestine.—Under the *serous* (*peritoneal*) *coat,* the small intestine possesses a very strong *muscular coat.* This consists of an outer longitudinal and an inner circular layer, both of which are complete and uninterrupted from the pylorus to the colic (ileo-cæcal) valve. The *mucous coat* is thick, and it is thrown into ridges, the *plicæ circulares* (*valvulæ conniventes*), which begin at the second part of the duodenum, and are most numerous in its third and fourth parts and in the upper part of the jejunum. Lower down they decrease in number, and they are entirely absent in the lower part of the ileum. In this situation the *aggregated lymph nodules* (*Peyer's patches*), which are not present in the jejunum, are fairly numerous and may measure 4 × ½ inches. They form somewhat granular patches in the mucous coat, and lie along the anti-mesenteric border of the gut.

Intestinal Stasis.—Near its termination, the ileum may become kinked and obstructed by a fibrous band, which varies in width from a half to two inches. It may pass downwards and to the right on the deep surface of the mesentery, or it may ascend from the pelvis as a thickening of the posterior parietal peritoneum. In the former case, the apex of the kink is directed upwards, and the proximal and distal limbs of the ileum, respectively, ascend and descend ; in the latter case, the condition is exactly reversed.

It is generally stated that these bands result from attacks of appendicitis, but Lane urges that those which hold the ileum up in the abdomen are produced naturally to give support to a prolapsing cæcum. The kinks may be observed in radiograms taken from ten to twelve hours after a bismuth meal. The constricted portion of the terminal part of the ileum is recognised by the narrow shadow of the contained bismuth, while the stronger wide shadows represent the proximal limb of the kink and the cæcum, which can be identified by its characteristic shape. It should be remembered that the shadow produced by a distended vermiform process, which is constricted near its base, may be misinterpreted as an ileal kink (Fig. 102).

The condition may be relieved by dividing the fibrous band transversely, but Lane contends that recurrence is certain and that ileo-pelvic-colostomy is necessary (p. 348), together with the removal of the intervening part of the large intestine. Good results follow resection of the cæcum and the terminal part of the ileum, with an end-to-side anastomosis between the ileum and the ascending colon.

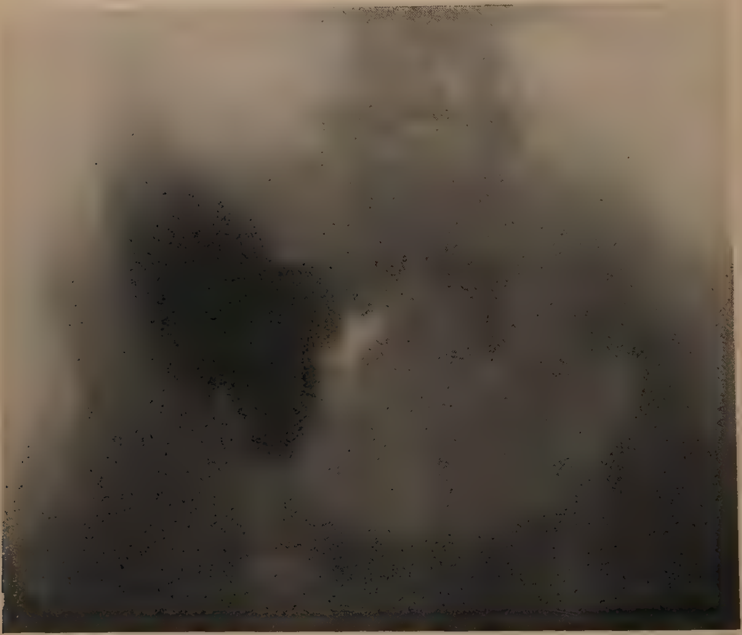

FIG. 102.—Partial Prolapse of the Cæcum. The Bismuth is also visible in the Vermiform Process, which passes towards the left and then turns downwards into the pelvis. The vermiform process in this radiogram resembles the appearance of a "Lane's Kink," but, at the subsequent operation, it was found in the position shown in the figure and with the bismuth still *in situ*.

Meckel's Diverticulum.—In the early human embryo the mid-gut communicates freely with the yolk-sac through the *vitello-intestinal duct*, which leaves the abdominal cavity at the site of the umbilicus (Fig. 89). As the embryo develops, the duct becomes occluded and later entirely disappears, but total or partial persistence of its intra-embryonic portion occurs in about two per cent of subjects. It is then known as a Meckel's diverticulum, and the condition constitutes the commonest congenital anomaly of the small intestine. Many varieties are met with, from a complete intestinal diverticulum opening at the umbilicus to a small elevation on the wall of the gut, but the diverticulum always springs from the anti-mesenteric border of the intestine and usually within three or four feet of the lower end of the ileum.

In *complete persistence*—congenital umbilical fistula—the duct may be several inches in length, or it may be so short that the ileum itself appears to open on the surface (Fig. 103, I). In the latter case the dorsal or mesenteric wall of the gut may prolapse through the opening, giving rise to a turgid swelling at the umbilicus and possibly causing intestinal obstruction. This condition presents an appearance very similar to that produced by the persistence of a small portion of the extra-embryonic part of the vitello-intestinal duct, which discharges mucus and is not necessarily associated with a Meckel's diverticulum (Fig. 103, IV). The passage of a probe at once serves to indicate which of the two varieties is present.

In *partial persistence* the duct is represented by a blind diverticulum which may sometimes be attached to the umbilicus by a fibrous cord (Fig. 103, V). The free diverticulum is the commonest variety; it is subject to inflammatory attacks and may form adhesions to any structure in its neighbourhood, often giving rise to intestinal obstruction. As the centres for the diverticulum and the vermiform process (appendix) occupy the same segment in the spinal medulla, the reflex sensory symptoms are very similar, and consequently inflammation of the diverticulum may easily be mistaken for appendicitis. In the cystic variety (Fig. 103, V) only the middle part of the intra-embryonic portion of the duct remains patent.

Differences between the Large and Small Intestine.—The large intestine differs from the small intestine in its outward appearance in several particulars. (1) The longitudinal muscular coat does not surround the large intestine completely. Instead, it forms three narrow bands, termed the *tæniæ coli,* which are visible through the serous coat. (2) The large intestine is *sacculated.* (3) *Appendices epiploicæ* are found on the large intestine; they consist of small peritoneal sacs filled with fat. (4) The wall of the large intestine is thinner than the wall of the small intestine. This difference is referable to the longitudinal muscular and the mucous coats.

These features of the large intestine are subject to a good deal of variation.

The **Colic (Ileo-Cæcal) Valve** is placed at the junction of the ileum with the large intestine, and it serves to demarcate the cæcum, which lies below it, from the ascending colon, which lies above it. The position of the valve may be indicated on the surface at the point of intersection of the intertubercular and the right lateral planes.

The valve consists of an *upper* and a *lower segment*, which bound a horizontal slit, directed forwards and to the right. The segments are produced by an invagination of the mucous, submucous, and circular muscular coats of the ileum and cæcum, but the longitudinal fibres and the serous coat take no part in their formation. Villi are found on the ileal surface of the valve, but the mucous membrane of its cæcal surface possesses the characteristic features of large intestine. Two ridges, which are known as the *frænula*, pass one from each end of the slit and run half-way round the gut.

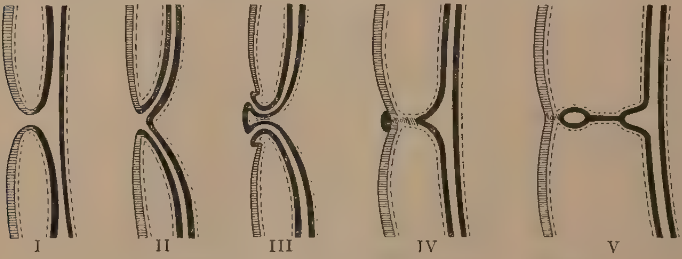

FIG. 103.—Diagrams to illustrate different degrees of Persistence of the Vitello-intestinal Duct.

I, II and III show different stages in the production of a hernia of the dorsal wall of the small intestine through a patent vitello-intestinal duct and umbilicus.

IV shows a patch of granulations at the umbilicus and a partially obliterated vitello-intestinal duct.

V shows incomplete obliteration of the vitello-intestinal duct with the formation of a small cyst near the umbilicus.

The heavy black lines represent the small intestine, and the shaded area represents the anterior abdominal wall. The dotted line represents the peritoneum.

The circular muscular fibres of the terminal part of the ileum constitute an *ileo-colic sphincter*, which is the real mechanism for regulating the flow of chyme into the cæcum and for preventing its regurgitation into the ileum.

The **Cæcum** is a blind sac about 2½ inches long and 3 inches wide. Normally it occupies the right iliac fossa, and is completely invested by the peritoneum, so that it can be lifted upwards and forwards out of the abdomen. It may sometimes possess a mesentery, or it may not be covered by peritoneum posteriorly, in which case it cannot be withdrawn from the abdomen until it has been mobilised (Fig. 104, 1). Owing to the laxity of the peritoneum, the normal range of movement may be considerably increased in some cases (*mobile cæcum*), and this may predispose to conditions of pericolitis, with symptoms closely resembling appendicitis.

A freely movable cæcum may *prolapse* into the pelvis and become distended with gas and fluid, which are hindered from escaping by the pressure of the pelvic brim and the superimposed coils of small intestine. As it enlarges, the over-distended cæcum drags down the parietal peritoneum, giving rise to painful symptoms. When the gut collapses, on the escape of its contents, the loose peritoneum over it fails to return to its former position owing to lack of elasticity and becomes wrinkled and thrown into vascular folds, which are known as "Jackson's veil." This condition is frequently seen in the region of the cæcum and ascending colon during operations for recurrent appendicitis. Its origin has been variously described as congenital, as a result of gradual ptosis of the cæcum, and as inflammatory following chronic pericolitis. "Jackson's veil" is very commonly seen in children and is often met with in the adult, but it is rarely to be observed in the cadaver.

Inferiorly, the cæcum is supported by the lowest part of the abdominal wall, and, when distended, it may form a palpable, and sometimes visible, tumour in this region, while gurgling can often be produced by manipulations. Owing to its proximity to the right abdominal inguinal (internal abdominal) ring, the cæcum and vermiform process are occasionally found in a right inguinal hernia in children.

In *structure* the cæcum resembles the rest of the large intestine. The longitudinal muscular coat forms three distinct bands or tæniæ. Of these one is found on the anterior surface of the bowel, a second on the posterior surface, while the third is placed on the medial surface. These three bands converge on the base of the vermiform process, which they provide with a complete longitudinal coat. The circular muscular coat, as in the small intestine, is uninterrupted, and the mucous coat contains a large amount of lymphoid tissue.

Three **peritoneal fossæ** or recesses occur near the termination of the ileum. (1) The *superior ileo-cæcal recess* (*ileo-colic*) lies in the angle between the ileum and the ascending colon. The anterior cæcal artery raises a fold of peritoneum from the posterior abdominal wall, and it forms the anterior boundary of the recess. The mouth of the fossa looks downwards and to the left.

(2) The *inferior ileo-cæcal* (*ileo-appendicular*) *recess* lies in the angle between the ileum and the cæcum. Its anterior wall is formed by the ileo-cæcal fold (bloodless fold of Treves), and its posterior wall is usually formed by the mesentery of the vermiform process. The ileo-cæcal fold is triangular in shape ; its apex is situated at the ileo-cæcal junction and its base is free, forming the anterior boundary of the mouth of the fossa.

(3) The *cæcal* (*retro-cæcal*) *fossa* is the largest and most constant of the fossæ in this region. It extends upwards behind the cæcum as far as the line of peritoneal reflection from that viscus to the floor of the iliac fossa. It is sometimes limited laterally by a fold which passes downwards and laterally across the lower part of the right para-colic gutter from the cæco-colic junction.

The **Vermiform Process** (**Appendix**) springs from the postero-medial aspect of the cæcum about one inch below the ileo-colic junction, and can always be found by tracing the anterior tænia coli downwards. It is usually about 3½ inches long and ¼ inch wide, but its length is very variable, being relatively greater in the child than it is in the adult. The orifice of the vermiform process communicates with the cæcum and is guarded by a crescentic fold of mucous membrane. Absence or incompetence of this valve may account for the presence of fæcal matter within the process.

The *mesentery of the vermiform process* is a triangular fold, which is derived from the left or lower layer of the mesentery of the ileum. It is sometimes shortened and attached to the posterior abdominal wall near the pelvic brim. Occasionally the vermiform process has no mesentery and is entirely retro-peritoneal.

Although its base is constant in position, in relation to the cæcum, the process itself possesses a wide range of movement and may occupy any one of the following situations :

(1) It may pass upwards and to the left, under cover of the mesentery ; this is known as the *splenic position*. When the process is retro-peritoneal in this situation, it may lie behind or within the root of the enteric mesentery.

(2) The vermiform process may pass downwards and to the left, occupying the *pelvic position*. Inflammatory attacks may give rise to adhesions which connect it to the rectum, bladder,

etc. In these cases defæcation or micturition may cause painful symptoms by traction on the adherent vermiform process, and an appendicular abscess may discharge by the rectum or the urethra. When the vermiform process occupies the pelvic position in the female, it is brought into close relationship with the right ovary; and if signs of inflammation occur, it may be a matter of great difficulty to decide whether the vermiform process or the right ovary is at fault. The relation of the pain to the menstrual period may aid in the diagnosis. Valuable information may be obtained by means of a rectal or a vaginal examination. When the process is retro-peritoneal in the pelvic position, it lies immediately in front of the common iliac vessels and the ureter, and difficulty may be experienced in mobilising it in appendicectomy.

(3) The vermiform process may pass forwards towards the anterior abdominal wall—the *anterior position*—but it can only do so when it possesses a mesentery. If it becomes inflamed in this situation the greater omentum usually surrounds it, and the mass so formed can often be recognised on abdominal palpation. Should an abscess form and rupture, the right infra-colic compartment may be infected (p. 289).

(4) The vermiform process very frequently takes up a position *behind the cæcum* and then has a varying relation to the peritoneum. (*a*) It may possess a mesentery and lie free in the cæcal (retro-cæcal) fossa. (*b*) It may be plastered on to the posterior aspect of the cæcum by the peritoneum, and it then lies in the anterior wall of the fossa. (*c*) In cases where the cæcum is not covered by peritoneum posteriorly, the retro-cæcal vermiform process lies in contact with the fascia iliaca and is only in contact with peritoneum at its base (Fig. 104, 5).

The course taken by an abscess in connection with a retro-cæcal vermiform process will depend on which of the three varieties is present. In (*a*) the abscess forms in the lowest part of the right para-colic gutter and reaches the anterior abdominal wall close to the anterior superior iliac spine. It then gives rise to a swelling, which is dull on percussion. Adhesions, however, may shut off the cæcal fossa so that the abscess, as it enlarges, pushes the cæcum forwards with the result that a tympanitic note is obtained on percussion over the swelling.

In (*b*) the abscess may rupture through the gut wall or it may burst into the cæcal fossa, in which event the condition is the same as that described for (*a*).

In (*c*) the abscess forms in the extra-peritoneal fat. The cæcum is thrust forwards against the anterior abdominal wall

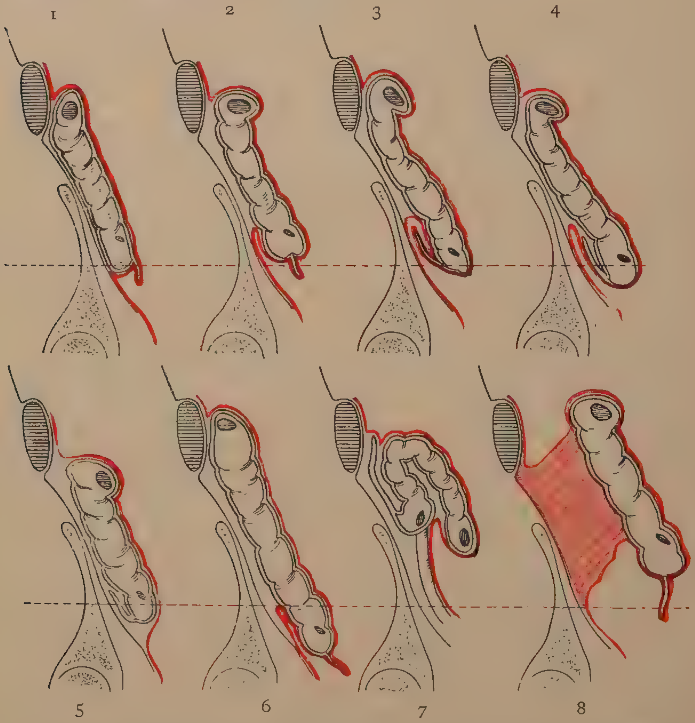

FIG. 104.—Diagrams to illustrate the varying relationships of the Cæcum, the Vermiform Process and the Ascending Colon to the Peritoneum.

1. Absence of cæcal fossa; posterior wall of cæcum not covered by peritoneum.
2. Normal condition. Cæcal fossa present.
3. Cæcal fossa extending upwards behind ascending colon. Vermiform process retro-cæcal in position but surrounded by peritoneum.
4. Vermiform process retro-cæcal in position but enclosed by the peritoneum surrounding the cæcum.
5. As 1 but vermiform process is entirely extra-peritoneal.
6. Prolapse of cæcum.
7. "Undescended cæcum." The terminal part of the ileum, as it ascends to the cæcum, is retro-peritoneal. The vermiform process is extra peritoneal except at its tip, which is lying in front of the kidney in the posterior wall of the hepato-renal recess. The ascending colon and the right colic flexure form a "double-barrelled" colon.
8. Ascending colon with persisting mesentery, such as is met with in intussusception.

Note.—The dotted line represents the position of the lumbo-sacral articulation.

so that a tympanitic note is obtained on percussion, and this may be misleading, unless the possibility of an extra-peritoneal abscess is kept in mind. Delay in recognising this condition allows the pus to spread upwards behind the peritoneum until it reaches the *extra-peritoneal subphrenic danger zone*.

Such an abscess may be evacuated by the extra-peritoneal route, but the access is rarely sufficient for removal of the vermiform process, and, further, a wide extent of cellular tissue is necessarily opened up. It is, therefore, better to empty it through the peritoneal cavity. The area medial to the ascending colon and cæcum is packed off, and the floor of the right para-colic gutter is incised. In this way the cæcum is rendered movable and can be retracted medially. The abscess can be evacuated and the vermiform process removed through the extended gridiron incision (p. 252).

(5) The infra-hepatic position is referred to on p. 349.

The **ileo-colic artery** arises from the superior mesenteric below the third part of the duodenum, and runs downwards and to the right in front of the right ureter and psoas major (Fig. 106). It breaks up near the ileo-colic fossa into branches which supply (1) the terminal part of the ileum, (2) the ascending colon, (3) the cæcum, and (4) the vermiform process. The cæcal arteries, anterior and posterior, supply the anterior and posterior surfaces of the cæcum. The artery to the vermiform process descends behind the ileum and enters the free border of the mesentery of the vermiform process. It does not anastomose with any other artery, and therefore, when it becomes kinked or obstructed, the blood-supply of the process is entirely cut off and gangrene ensues.

Intussusception.—A condition of incipient intussusception is always present on account of the invagination of the circular muscular coat into the segments of the colic (ileo-cæcal) valve. This constitutes a predisposition to *ileo-cæcal intussusception*, but the condition can only occur when the ascending colon possesses a mesentery. The frequency of its incidence during the first year is explained by the fact that the relative disproportion in calibre between the large and small intestine is greatest at that period.

It is said that if a wave of peristalsis passes up the cæcum just as one ends on the ileum, the colic valve, which is at that moment projected furthest within the lumen of the cæcum, is seized by the contracting cæcum and squeezed upwards along the ascending colon. When the angle at which the ileum joins the colon is greater than 90°, intussusception occurs more readily.

In this variety *the colic valve forms the apex of the* *intussusceptum*, and as it passes along the large intestine, the cæcum, vermiform process and ascending colon are dragged in together with the ileum and its mesentery. Finally, the colic valve may appear at the anus.

In the *ileo-colic variety* the intussusception begins in the ileum, usually near its terminal portion. The part of the gut which constitutes the starting-point of the condition remains at the apex of the intussusceptum (Fitzwilliams), both before and after it has passed through the colic valve. If the ascending colon possesses a mesentery, the subsequent course of events is the same as in the ileo-cæcal variety. If the ascending colon has no mesentery, the intussusception stops at the valve.

The **Ascending Colon** runs upwards on the iliacus, the quadratus lumborum, and the lower pole of the right kidney (Fig. 88); it is separated from both muscles by their fascia and from the kidney by the peri-nephric fascia. It separates the right para-colic gutter from the right infra-colic compartment, and is bound to the posterior abdominal wall by the peritoneum, which clothes its anterior, medial, and lateral surfaces. Occasionally the right margin of the greater omentum is fused with the peritoneal covering of the ascending colon. In that case the right half of the transverse colon is often closely related to the ascending colon, forming what has been termed the "double-barrelled gun" arrangement (Fig. 105).

The **Right Colic (Hepatic) Flexure** lies under cover of the ninth and tenth costal cartilages in the interval between the inferior surface of the right lobe of the liver and the anterior surface of the lower pole of the right kidney. It is formed by the terminal part of the ascending colon, which turns downwards, forwards, and to the left to become continuous with the transverse colon. Its medial surface is in contact with the gall-bladder, anteriorly, and with the second part of the duodenum, posteriorly.

When the body is in the supine position, the flexure lies a little below the transpyloric plane, but radiograms show that, in the erect posture, it descends, sometimes even to the level of the iliac crest (fourth lumbar vertebra). The amount of peritoneum which persists in this region is very variable, and this fact may account for the wide range of movement.

The **Transverse Colon** extends from the right to the left colic flexure. As it crosses the abdominal cavity it takes a downward curve, usually reaching its lowest point in the middle line where, in the supine position, it lies at or a little below the umbilicus. In many cases, however, the transverse colon is placed at a much lower level, and its position depends on (1) its length, which may be greatly increased, *e.g.* in cases of undescended cæcum (p. 349), and (2) the length of the transverse meso-colon.

In the erect posture the transverse colon descends still further, and is often seen lying behind the pubic symphysis. Under these circumstances, the right and left colic flexures become very acute, and the proximal part of the transverse colon descends in front of or medial to the ascending colon. If these two pieces of bowel are attached to one another by peritoneal bands (p. 338) or adhesions, the kinking will persist in the supine position and may give rise to delayed peristalsis and chronic constipation.

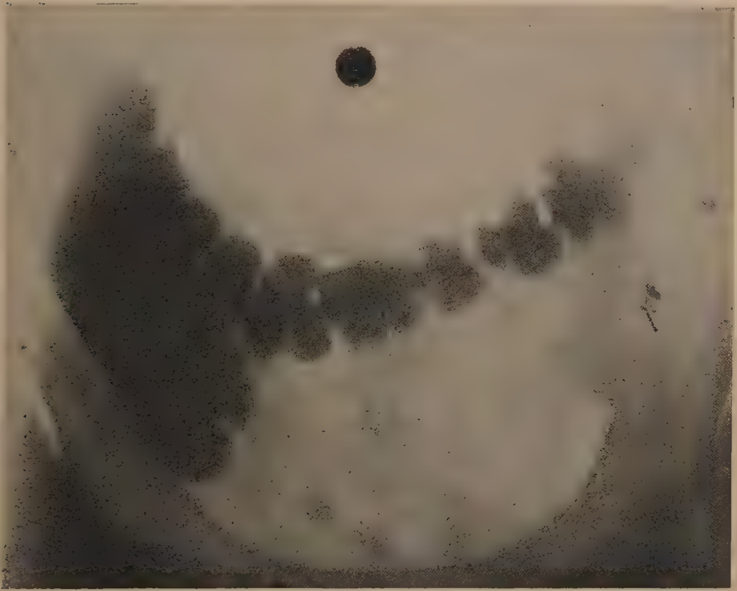

FIG. 105.—"Double-barrelled" Colon. The dark mass on the left of the figure consists of the cæcum, the ascending colon and the first part of the transverse colon.

The transverse colon is completely surrounded by peritoneum except along narrow strips on its upper and lower surfaces, where the transverse meso-colon and the greater omentum reach the gut (Fig. 85).

The **transverse meso-colon** suspends the transverse colon from the posterior abdominal wall. It is attached normally to the front of the head, neck, and body of the pancreas, but it may extend further over to the right and cross the anterior surface of the second part of the duodenum. It separates the cavity of the omental bursa from the infra-colic compartments (Fig. 85), and is related to the stomach, anteriorly, and to the duodeno-jejunal flexure and coils of small intestine, posteriorly. The two layers of the transverse meso-colon contain the middle colic vessels, lymphatics, and nerves.

The Blood-supply to the ascending colon, right colic flexure, and the transverse colon is derived from (1) the right and (2) the middle colic branches of the superior mesenteric artery.

(1) The *right colic artery,* which often arises by a common trunk with the ileo-colic, runs to the right, behind the peritoneum of the right infra-colic compartment. It crosses in front of the right psoas major, ureter, and spermatic vessels, and usually lies a little below the right kidney. Near the gut it divides into a descending branch, which anastomoses with the colic branch of the ileo-colic, and an ascending branch, which anastomoses with the right division of the middle colic. Both branches supply the ascending colon (Fig. 106).

(2) The *middle colic* arises from the superior mesenteric at the lower border of the pancreas and enters the root of the transverse meso-colon. Between its two layers the artery passes downwards and to the right to supply the transverse colon. It divides into a right branch, which supplies the right third of the transverse colon and anastomoses with the ascending branch of the right colic near the right colic flexure; and a left branch, which supplies the left two-thirds of the transverse colon and anastomoses with the ascending branch of the left colic near the left flexure of the colon. As the artery lies somewhat to the right of the middle line, openings in the transverse meso-colon are made on the left side (p. 305).

The **lymph vessels** of that portion of the large intestine which is supplied by the superior mesenteric artery mainly follow the course of the chief blood-vessels. The *lymph glands* are divided by Jamieson and Dobson into four groups. (1) The *epi-colic lymph glands* are situated on the wall of the gut. (2) The *para-colic lymph glands* lie on the medial side of the ascending colon behind the posterior parietal peritoneum; and above the transverse colon, between the two layers of its mesentery. (3) The *intermediate lymph glands* are associated

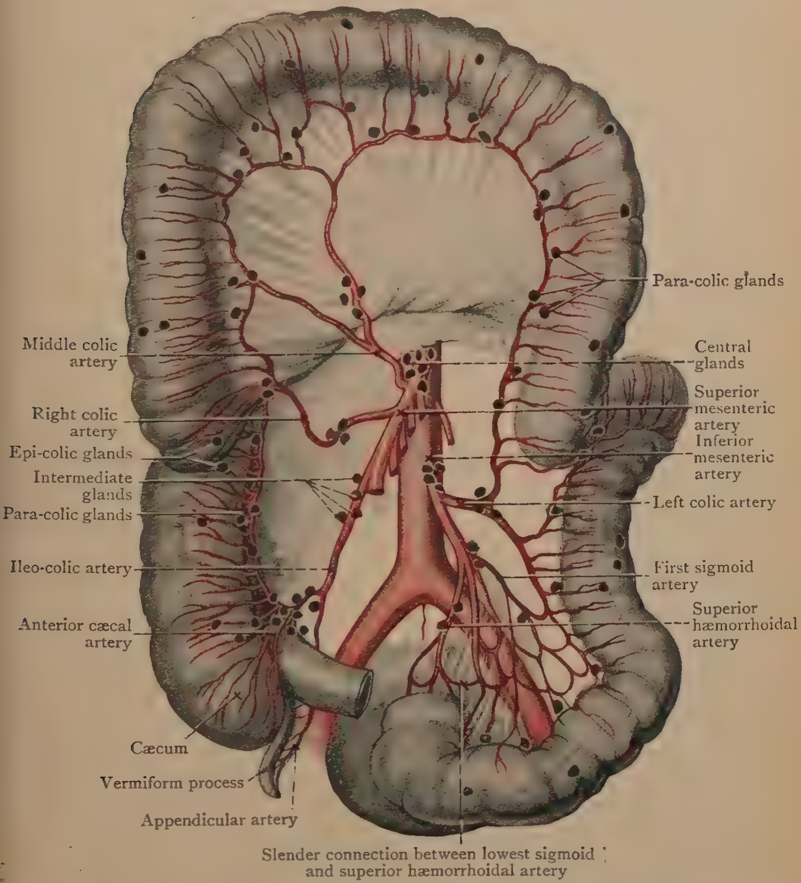
Para-colic glands
Middle colic artery
Central glands
Superior mesenteric artery
Right colic artery
Inferior mesenteric artery
Epi-colic glands
Intermediate glands
Left colic artery
Para-colic glands
Ileo-colic artery
First sigmoid artery
Superior hæmorrhoidal artery
Anterior cæcal artery
Cæcum
Vermiform process
Appendicular artery
Slender connection between lowest sigmoid and superior hæmorrhoidal artery

FIG. 106.—The Arteries and Lymph Glands of the Large Intestine.

with the ileo-colic, right, and middle colic vessels. (4) The *central group* lies along the superior mesenteric vessels (Fig. 106).

Efferents pass from the epi-colic to the para-colic lymph glands, from the para-colic to the intermediate group, and from the intermediate to the central group. Some efferents from the bowel and epi-colic lymph glands pass directly to the intermediate group, and, on this account, the latter must be removed together with the bowel and the para-colic lymph glands in malignant disease *vide infra*. In removing retro-peritoneal lymph glands, the peritoneum which covers them must also be taken away. This leaves a part of the posterior abdominal wall bare, and the surrounding peritoneum requires to be undermined before it can be drawn together over the denuded area.

Removal of Cæcum and Ascending Colon.—The parts dealt with in this operation are more or less fixed in position, and their blood and lymph vessels lie behind the posterior parietal peritoneum. For these reasons the resection of the ascending colon presents more difficulty than the removal of a part of the small intestine, where the gut is freely movable and its blood and lymph vessels are easily controlled as they lie in the mesentery.

The extent of malignant or tuberculous disease in the ileo-cæcal region may be so limited that only a comparatively small piece of the gut requires to be removed. If, however, the right colic (hepatic) flexure is not freely movable, some difficulty may be experienced in approximating the two cut ends in the subsequent anastomosis. Under these circumstances it is advantageous to remove the flexure in addition to the diseased area, and the more movable transverse colon can then be united to the ileum.

After the abdomen has been opened (p. 254), the surgeon (1) may first ligature the ileo-colic and right colic arteries and then proceed to free the bowel; or (2) he may free the bowel first and secure the vessels at a later stage. In the first method the vessels are found behind the peritoneum on the posterior wall of the right infra-colic compartment (Fig. 107).

In the second method a vertical incision is made through the peritoneum of the floor of the right para-colic gutter in its whole extent, and it is then continued to the left behind the cæcum and below the ileum. The cæcum and ascending colon are then freed by dissecting with the fingers, and the peritoneum is stripped off the posterior wall of the right infra-colic compartment. During these stages of the operation care must be taken not to injure the right spermatic vessels, ureter, or the second part of the duodenum (Fig. 107). The contents of the right iliac fossa can now be drawn out of the abdomen and turned over towards the left. While this is being done, the right colic and ileo-colic vessels are secured on the *deep* surface of the peritoneum. The ileum and ascending (or transverse) colon are then clamped and divided, and the intervening portion of bowel is removed, together with the adjoining area of peritoneum up to the point where the arteries have been ligatured. As the ileo-colic artery has been tied, the terminal six inches of the ileum is dependent for its blood-supply on the anastomosis between the ileo-colic and the termination of the superior mesenteric. It is thus rendered unsuitable for intestinal anastomosis and must be resected in order that the piece of the ileum which is utilised for this purpose may possess a free and ample blood-supply.

The **Left Colic (Splenic) Flexure** is deeply situated under cover of the costal margin and is partially overlapped by the stomach. On this account its examination is by no means easy, and, therefore, tumours of the flexure are not readily recognised at an early stage. Radiograms demonstrate that its position is very constant. It lies under cover of the eighth rib and its costal cartilage, to the left side of the left lateral line. Its upper aspect receives the attachment of the upper end of the left border of the greater omentum ; its posterior surface is attached to the pancreas by the left extremity of the transverse meso-colon ; and, from its lateral aspect, the peritoneum passes to the diaphragm forming a fold, which is called the phrenico-colic ligament. Superiorly, the flexure is in contact with the lower end of the spleen, and, posteriorly, it rests on the lateral part of the anterior surface of the left kidney.

The *left colic artery*, which is a branch of the inferior mesenteric, runs upwards and to the left, behind the peritoneum of the left infra-colic compartment and in front of the internal spermatic vessels, ureter, and kidney. Before it reaches the left colic flexure, the artery divides into a *descending branch*, which runs downwards along the medial border of the descending colon, and an *ascending branch*, which supplies the flexure and then enters the transverse meso-colon to supply the transverse colon and anastomose with the left branch of the middle colic.

The *lymph vessels* of the left flexure pass through the epi- and para-colic lymph glands to reach the intermediate group on the left colic artery. Jamieson and Dobson state that a few lymph vessels from the flexure enter the splenic lymph glands, and that, on this account, complete removal of the lymphatic area in malignant disease of the flexure is impossible.

Resection of the left colic flexure involves the removal of the left third of the transverse colon and the upper part of the descending colon. This necessitates the division of (1) the peritoneum in the left para-colic gutter, (2) the phrenico-colic ligament, (3) the left part of the greater omentum, and (4) the left part of the transverse meso-colon. In this way the flexure is mobilised, and it can then be stripped downwards and medially by the fingers. During this process care must be exercised not to injure the kidney or ureter (cf. resection of right flexure, p. 342). The ascending branch of the left colic artery is ligated on the posterior surface of the peritoneum, and the left branch of the middle colic is caught before the transverse colon and meso-colon are divided.

The **Descending Colon** is about four inches long and extends from the left flexure down to the iliac crest. Above, it lies in the angle between the left kidney and the transversus abdominis; below, it lies on the quadratus lumborum. It separates the left infra-colic compartment from the left para-colic gutter, and, anteriorly, it is in relation to the terminal part of the transverse colon above, and to coils of small intestine below. The peritoneum covers the descending colon in front and on each side, but this part of the gut rarely possesses a mesentery. The descending colon is in direct contact with the extra-peritoneal fat (p. 279).

The **Iliac Colon** descends on the iliacus muscle to the level of the antero-superior iliac spine and then turns medially, parallel to, and a little above, the inguinal ligament. It forms the medial boundary of the left para-colic gutter and ends, at the brim of the pelvis, by becoming continuous with the pelvic colon. Like the descending colon, the iliac colon is retro-peritoneal and rarely possesses a mesentery. Tumours of the iliac colon are not difficult to recognise, as they may be palpated by rolling the gut against the ilium. Scybalous masses may be distinguished by the fact that they can be pitted on firm pressure.

The **Pelvic Colon,** which varies from ten to thirty inches in length, is continuous with the iliac colon above and terminates in front of the third piece of the sacrum, where it becomes continuous with the rectum. It is suspended from the posterior wall of the pelvis by a mesentery, termed the **pelvic meso-colon,** and consequently is freely movable. The line of attachment of its mesentery resembles an inverted V. It begins on the medial border of the psoas major and passes upwards and medially along the medial side of the external iliac vessels. After crossing the hypogastric (internal iliac) artery, it bends sharply downwards and ends in front of the third sacral vertebra. On account of the arrangement of the mesentery, the terms *ascending* and *descending limbs* are used with reference to the pelvic meso-colon and to the parts of the gut which they enclose.

A small intra-peritoneal fossa, termed the *intersigmoid recess*, lies at the apex of the inverted V and is bounded on each side by the left or lower layer of the pelvic meso-colon. This recess is sometimes the site of an intra-peritoneal strangulated hernia.

The pelvic colon is usually situated partly in the pelvis and partly in the abdomen. When it possesses a long mesentery, it may pass across the median plane, and it is not infrequently seen during the operation of appendicectomy. In the child it lies mainly in the abdomen, owing to the relatively small size of the pelvic cavity.

The advantage taken by the surgeon of a freely movable pelvic colon is pointed out on p. 347.

The **Inferior Mesenteric Artery** arises from the abdominal aorta 1½ inches above its bifurcation. It runs downwards and slightly to the left, and gives off the *left colic* (p. 341) and the *sigmoid arteries*. Its downward continuation into the pelvis is called the *superior hæmorrhoidal artery*.

The *sigmoid arteries*, three or four in number, supply the iliac and pelvic cola. They anastomose freely with one another, forming arterial arcades across the iliac fossa and in the pelvic meso-colon. The highest of the series similarly anastomoses with the descending branch of the left colic. The anastomosis between the lowest sigmoid and the superior hæmorrhoidal is not always sufficient to re-establish the circulation, if the inferior mesenteric artery is ligatured beyond the origin of the lowest sigmoid branch. In abdomino-perineal or abdomino-sacral removal of the rectum, the inferior mesenteric requires to be ligated. If the ligature is applied below the origin of the lowest sigmoid artery, the vitality of the lower part of the pelvic colon is seriously imperilled. It is necessary, therefore, to apply the ligature on the proximal side of the lowest sigmoid branch. The anastomosis between the sigmoids is sufficient to ensure the passage of blood through the lowest sigmoid back into the inferior mesenteric, and thus the blood-stream reaches the pelvic colon along the normal channel.

The **nerve supply** to the large intestine (with the exception of the rectum and anal canal, p. 375) is chiefly derived from the sympathetic plexuses which accompany the superior and inferior mesenteric arteries (T. 12, L. 1 and 2).

Colotomy.—The pelvic colon is usually selected as the site for an inguinal colotomy on account of its wide range of movement. A loop of the gut with its mesentery is brought out of the abdomen through the left rectus and its sheath, or through a gridiron incision which is made at a slightly lower level than the appendicular incision (p. 252) on the opposite side. A glass rod or rubber tube is passed through the mesentery to support the bowel by resting on the skin surface on each side of the wound, and the serous and muscular coats of the colon are stitched to the parietal peritoneum.

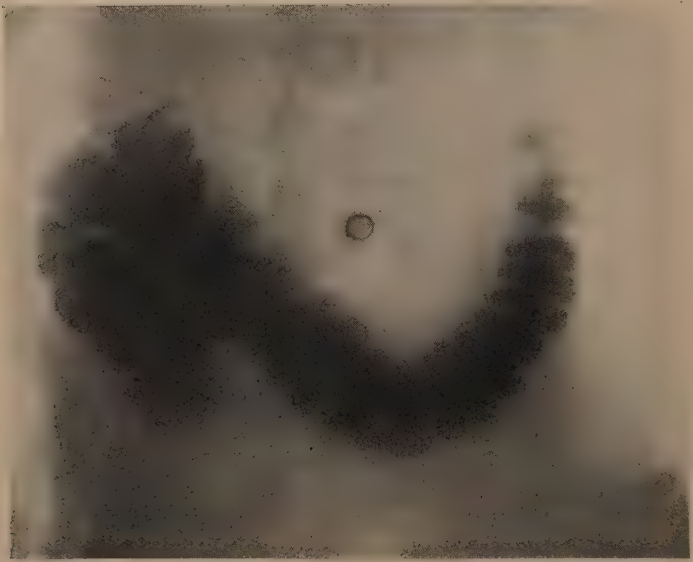

FIG. 107.—Radiogram of the Cæcum, the Ascending Colon, the Right Colic (Hepatic) Flexure, and the Transverse Colon in a Normal Subject. The position of the transverse colon relative to the umbilicus and the position of the cæcum relative to the pelvic inlet should be noted.

Owing to the circular course followed by the blood-vessels in the wall of the gut, the colotomy opening is made transversely.

If complete division of the bowel and its mesentery is carried out, only one or two small vessels in the edge of the pelvic meso-colon require to be tied. This part of the operation is quite painless and may be carried out without any anæsthetic.

Many surgeons prefer to make the opening near the commencement of the pelvic colon, because when a more distal portion is used there is subsequently a distinct tendency to prolapse of the mucous membrane. On the other hand, when the opening is made in the lower part of the pelvic colon, the proximal loop of the pelvic colon acts as a reservoir.

In some cases the pelvic colon and meso-colon are so short that it is impossible to bring the bowel out at the abdominal wound. It is then necessary either to mobilise the iliac colon by dividing the peritoneum freely along the left paracolic gutter, or to utilise the transverse colon or the cæcum.

The **Excision** of a part of the pelvic colon presents little difficulty when the gut possesses a long mesentery, and axial anastomosis may be carried out. When the pelvic meso-colon is short it may be necessary to mobilise the lowest portion of the iliac colon. This can be effected by dividing the peritoneum along the left para-colic gutter and stripping the bowel medially on a hinge of peritoneum. The lateral cutaneous nerve of the thigh, the ductus deferens, the internal spermatic vessels, and the genito-femoral nerve may be injured unless care is exercised at this stage of the operation. In addition, the ureter, which is crossed by the root of the pelvic meso-colon near the apex of the V, and the inferior mesenteric artery and its terminal branch which runs downwards in the descending limb of the pelvic meso-colon (Fig. 88), must all be preserved.

Transplantation of Ureters.—The mobility of the pelvic colon renders it suitable for the implantation of the divided ureters in cases of extroversion of the bladder and in epispadias (in both sexes) with associated incontinence of urine (Stiles). It might be supposed that the introduction of the ureters into a septic tube would lead to an ascending infection of the urinary tract, but provided that the urine, ureters, and kidneys are healthy there is no risk of such an occurrence. After the operation the bowels may be unnaturally loose for a time, but the rectum rapidly becomes tolerant of the presence of the urine so that the bowels act only once or twice a day.

The operation of transplantation is performed in *two* stages, an interval of a fortnight being allowed to elapse before the second ureter is transplanted.

Very careful preparation of the patient on each occasion is essential to ensure an empty pelvic colon.

The patient is placed in an exaggerated Trendelenburg position in order to facilitate the exposure of the ureters. A vertical incision through the left rectus gives good access, due care being taken to ligate the inferior epigastric artery. In the case of the *left ureter*, the coils of small intestine are displaced upwards, and the pelvic colon is identified. It is then turned upwards, and the peritoneum in the floor of the intersigmoid fossa (Fig. 88) is carefully divided. The pelvic portion of the ureter is now exposed and may be traced downwards and freed before it is ligated and divided. Its extremity is then implanted into the ascending limb of the gut, and the adjacent part of it is buried in the wall of the bowel after the manner adopted in Witzel's gastrostomy. The peritoneal and abdominal incisions are then closed.

The *right ureter* is found near the medial border of the right psoas major, after it has been crossed by the root of the mesentery (Fig. 88). The peritoneum over it is carefully incised, and it is then traced downwards and divided. The cut end is then approximated to the descending limb of the pelvic colon, and the implantation is carried out as before.

In **Ileo-Pelvic-Colostomy** an anastomosis is established between the terminal part of the ileum and the pelvic colon. The operation is performed in chronic intestinal stasis, or for threatened obstruction in the intervening parts of the large bowel. It is carried out with the pelvis slightly elevated, and good access is obtained by a median infra-umbilical incision.

Care must be taken to divide the ileum on the proximal side of any obstructing bands (p. 329), and in such a way that it can be connected to the pelvic colon without any subsequent tension on the anastomosis. After the ileum has been cut through, the mesentery is divided very slightly to facilitate the invagination of the distal cut end of the gut. In bringing the ileum into apposition with the pelvic colon, its cut end must be rotated *counter-clockwise* in order that the left or lower surface of the mesentery may lie in contact with the right surface of the descending limb of the pelvic meso-colon. If the cut end is rotated in the opposite direction, the enteric mesentery is twisted and the ileum may subsequently become kinked. The anastomosis between the cut end of the ileum and the side of the descending limb of the pelvic colon is then completed. As a result the anastomosis forms a bridge in front of a patent passage between the mesentery and the pelvic meso-colon, and in order to prevent the occurrence of an intra-peritoneal strangulated hernia the two mesenteries are closely drawn together by means of a linen-thread purse-string suture.

Development of the Intestines.—The alimentary canal caudal to the stomach elongates much more rapidly than the posterior abdominal wall, and the growth of the mesentery keeps pace with it. A U-shaped loop is thus formed, which passes out of the abdomen through the patent umbilicus (p. 292), carrying down the superior mesenteric artery between the two layers of the mesentery. An evagination appears on the distal limb of the U and subsequently forms the cæcum and the vermiform process. In the early stages of development the gut becomes *rotated* round the superior mesenteric artery, so that the distal limb of the loop is carried across the ventral surface of the proximal limb (Fig. 90). When the loop is withdrawn from the umbilical cord (p. 292) it is found that, as a result of this rotation, the transverse colon crosses in front of the duodenum.

Thereafter, the mesentery of the large intestine partially disappears and only persists for the transverse and pelvic cola. After the rotation the transverse colon lies behind the greater omentum (p. 307), and its mesentery blends with the two posterior layers of the latter so that this part of the gut attains the peritoneal relationship which is found in the adult.

The cæcal outgrowth rapidly increases in length. Its proximal fourth or less forms the cæcum, and its distal part forms the vermiform process. At birth the cæcum is conical in shape and the vermiform process is attached to its apex. This condition may persist—*the infantile cæcum*—but, normally, the lateral wall of the cæcum increases more rapidly than the medial wall, and in the adult the vermiform process springs from the latter. After the viscera are withdrawn from the umbilical cord (p. 292) into the abdomen, the cæcum lies in relation to the under surface of the liver in continuity with the transverse colon. As the colon increases in length, the cæcum gradually descends, and at birth it lies in the right iliac fossa. *Mal-descent or non-descent* is a well-recognised anomaly and the cæcum is then frequently of the infantile type. When it is not found in its normal position in abdominal operations the possibility of this condition must be borne in mind.

Prior to the descent of the cæcum the vermiform process may take up a retro-cæcal position, and it may become fixed in this situation, losing its peritoneal covering. When the cæcum descends the vermiform process is left behind in the extra-peritoneal retro-cæcal position (Fig. 104, 7).

Sometimes the rotation of the intestines is incomplete, so that the cæcum is carried across the duodenum to its left side. It will then be found, together with the vermiform process, between the two layers of the transverse meso-colon, while the terminal part of the ileum occupies the areas in which the cæcum, ascending colon, and right colic flexure are normally found.

Very rarely rotation fails to occur. The colon then occupies the lower and left part of the abdominal cavity, the small intestine lying above and to the right. The ileum enters the right side of the cæcum and no part of the colon is connected with the greater omentum.

The mesenteries of the ascending, descending, and iliac cola often persist during childhood and disappear later. This accounts for the incidence of intussusception, in which the whole length of the large intestine commonly possesses a mesentery. More rarely, an excess of peritoneum may persist in the adult, and such a persistence may explain the condition of "mobile cæcum," and the accompanying "Jackson's veil" (p. 333).

The **Kidneys** lie, one on each side of the vertebral column, opposite the twelfth thoracic, first, second, and third lumbar vertebræ, but owing to the large size of the right lobe of the liver the right one usually lies at a somewhat lower level than the left. The kidney is about 2 inches wide and 4½ inches long, and its long axis is directed from above downwards and laterally. The upper pole is limited above by a horizontal plane drawn midway between the transpyloric plane and the xiphisternal junction; the lower pole extends to the subcostal plane. The transpyloric plane passes through the hila of both kidneys at about 1½ inches from the median plane. When the position of the hilum is determined on the surface it is not difficult to map out the kidney with the help of the facts which have been enumerated.

The **Ureters** may be indicated on the anterior abdominal wall by lines drawn downwards from each hilum at a distance of 1½ inches from the median plane. These vertical lines trisect the line joining the anterior-superior iliac spines at points which correspond to the bifurcations of the common iliac arteries. These vertical lines correspond to the abdominal parts of the ureters and pass through the tips of the lumbar transverse processes. The pelvic part of the ureter may be indicated by a line which curves downwards and medially, with a slight downward convexity, from the iliac bifurcation to the pubic tubercle (spine).

Posteriorly, the transpyloric plane passes through the lower border of the first lumbar spine. The hilum of the kidney lies 1½ inches lateral to the spine of the first lumbar vertebra, and the whole kidney can be mapped out on the dorsal surface of the body from the measurements already given.

The abdominal part of the ureter corresponds to a line drawn from the hilum to the postero-inferior iliac spine (Fig. 84).

A knowledge of the topography of the kidneys and ureters is essential for the correct interpretation of radiograms, in which the question arises as to whether a certain shadow may or may not be produced by a calculus.

The shadows thrown by phleboliths or calcareous deposits in the mesenteric or iliac lymph glands may be difficult to distinguish from shadows caused by ureteral calculi (Figs. 108, 109, and 113). Phleboliths, however, are much more commonly found in the vesico-prostatic veins (p. 368), but even in this position they may throw shadows in relation to the vesical openings of the ureters.

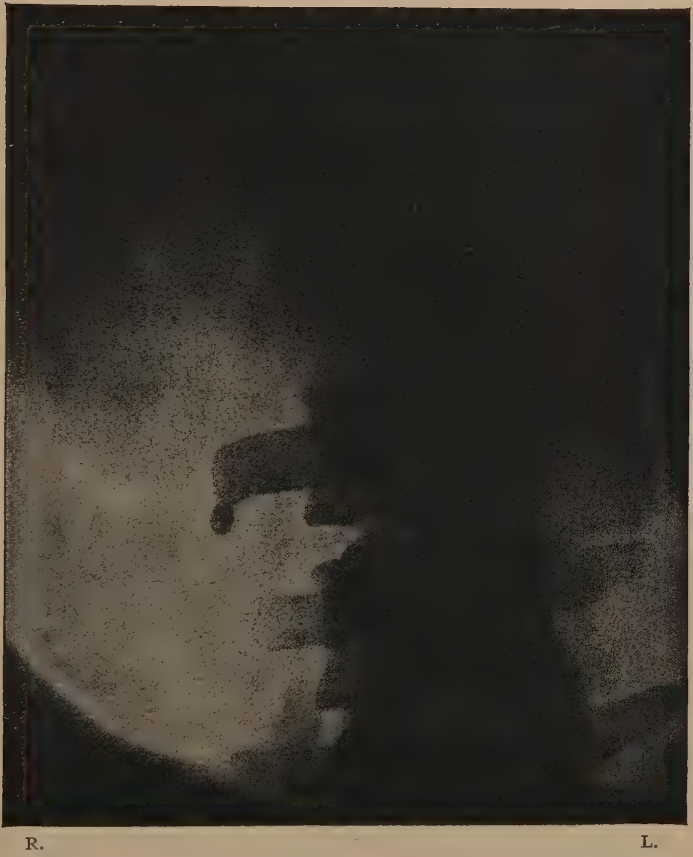

FIG. 108.—Small Calculus impacted in the Right Ureter. The radiogram was taken a few days after an attack of right renal colic. The outline of the lower pole of the kidney is faintly visible. (Bythell and Barclay's *X-ray Diagnosis and Treatment.*)

Although the normal line of the ureter passes through the tips of the lumbar transverse processes, shadows found more medially may nevertheless be due to ureteral calculi, because when hypertrophied as the result of urinary obstruction, the ureter takes an irregular downward course.

The peri-nephric fascia and the posterior relations of the kidneys have already been described (p. 275).

The **Right Kidney** is in contact, *anteriorly*, with the suprarenal gland, the liver, the right colic flexure, and the duodenum. The suprarenal gland lies on its upper pole, and below that, the liver covers nearly two-thirds of its anterior surface. The second part of the duodenum lies along the medial border overlapping the hilum, and the right colic flexure covers the infero-lateral part of this surface. Over the hepatic area the peritoneum is in direct contact with the kidney, forming the posterior wall of the hepato-renal recess (p. 286); elsewhere it is lifted off by the related viscera.

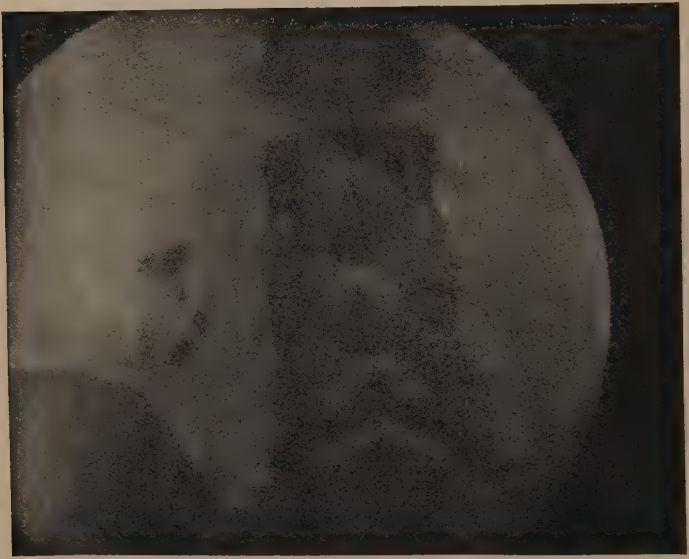

FIG. 109.—Radiogram showing Tuberculous Mesenteric Lymph Glands.

Excision of the Right Kidney may require to be performed from the front, when the viscus is too large to be removed through the loin. A long vertical incision is made through the anterior abdominal wall, commencing above at the tenth costal cartilage. Owing to the length of the wound, the ninth, tenth, and eleventh intercostal nerves have to be sacrificed as free access is essential. The abdominal cavity having been opened, the peritoneum is incised along the upper part of the right para-colic gutter and the hepato-renal recess. It is carefully stripped off the hepatic area, and the ascending colon, right colic flexure, second part of the duodenum, and the head of the pancreas are turned medially. In this way the anterior surface of the kidney is exposed, and the pedicle formed by the renal artery and vein can be defined by careful blunt dissection. The vein is the most anterior structure at the hilum and the ureter and its dilated pelvis the most posterior, while the artery occupies an intermediate position. The ureter is ligated in two places and divided. Next a ligature is passed round the vascular pedicle and the artery and vein may then be ligated separately nearer to the kidney. The viscus is removed, after it has been separated from the surrounding peri-nephric fat.

In advanced tuberculous disease and hydronephrosis the vascular supply may be much diminished, and it may be impossible to define the vascular pedicle owing to the presence of adhesions. Care must be exercised in these cases not to exert traction on the kidney, because the right renal vein, which is a short vessel, may tear away from the inferior vena cava. This risk can sometimes be avoided by splitting the capsule and shelling out the kidney from inside. The bleeding vessels can be secured as they are encountered, and subsequently portions of the capsule can be cut away.

The **Left Kidney** is crossed at about the middle of its anterior surface by the pancreas and splenic vessels (Fig. 87). Above the pancreas, the left kidney is related to the spleen, laterally, and to the suprarenal gland, medially. The area between these two viscera lies in the posterior wall of the omental bursa and forms a part of the stomach bed. Below the pancreas, the first coil of the jejunum covers the whole surface except a strip along the lateral border, which is in contact with the left colic flexure and the descending colon.

The peritoneum is lifted off the kidney by the descending colon, the pancreas, and the suprarenal gland, which are all in direct contact with the viscus. The lieno-renal ligament reaches the kidney above the pancreas, and its right layer is continued over the gastric area, while its left layer covers the area in contact with the spleen (Fig. 87). The area related to the jejunum is covered by the downward continuation of the lower layer of the transverse meso-colon.

It should be noted that the left kidney is found in three regions, viz. (1) the omental bursa, (2) the left infra-colic compartment, and (3) the lieno-renal recess, at the upper end of the left para-colic gutter.

Excision of the Left Kidney is carried out by a method very similar to that adopted for the right kidney. After the abdominal cavity has been opened, the peritoneum in the upper part of the left para-colic gutter, the phrenico-colic ligament, and the peritoneum along the upper part of the lateral border of the kidney are all incised. The descending colon and left colic flexure are then stripped medially and the whole of the anterior surface of the kidney can be exposed.

The peritoneum must not be incised along the medial border of the bowel lest the colic vessels be injured. Further, in the excision of either kidney, the possible presence, generally at the lower pole, of one or more supernumerary renal arteries must be remembered.

The trans-peritoneal operation for excision of the kidney possesses one great advantage over the lumbar or extra-peritoneal operation, namely, that the surgeon is able to palpate both kidneys through the incision in the abdominal wall.

Structure of the Kidney.—The hilum of the kidney leads into a space, termed the renal sinus, into the cavity of which numerous renal papillæ project. On section, the kidney is seen to possess a narrow cortical and a deeper medullary layer. The latter is darker in colour and striated in appearance, and is subdivided into a number of small pyramids, the apices of which constitute the renal papillæ.

At the hilum the ureter becomes greatly dilated to form the renal pelvis (pelvis of ureter), which divides into two or sometimes three calyces majores. Each calyx major subdivides into smaller calyces, and each of the latter is associated with one or more renal papillæ, receiving the urine from the uriniferous tubules which open on their surfaces.

Calculi may form in the kidney, calyces, or renal pelvis, and give rise to hydronephrotic changes by obstructing the urinary outflow ; on the other hand, a stone may lie latent for a considerable period.

A stone or stones lying in the renal pelvis may be removed by incising the pelvis and without cutting into the kidney. This is best carried out by the lumbar route, and after the kidney has been brought to the surface, it is turned slightly forwards and the pelvis is incised horizontally. Occasionally one or more of the renal vessels may intervene, but these may be retracted out of the way. The pelvis heals extremely readily, and there is no danger of establishing a fistula.

The **Renal Arteries** arise from the aorta a little below the transpyloric plane. The *right* one passes behind the vena cava inferior, the head of the pancreas, the second part of the duodenum, and its own vein. The *left* one passes behind the body of the pancreas and the left renal vein.

In the renal sinus the terminal branches of the renal artery divide into *ventral* and *dorsal groups*. Brödel has pointed out that an incision along the convex lateral margin of the kidney cuts through the principal arteries of the ventral group, and he suggests that incisions should be made slightly behind that border so as to pass between the two groups. When this is done successfully, the hæmorrhage is not so great, and it is easily controlled by compression of the vascular pedicle.

Supernumerary renal arteries may be present on either side. They usually arise from the aorta and enter the medial border of the kidney near its lower pole. Sometimes they ascend from the common iliac or they may arise above the normal renal and enter the upper pole. Their occurrence must always be borne in mind in excision of the kidney.

The **Renal Veins** terminate in the inferior vena cava at the transpyloric plane. Owing to the position of the vena cava on the right side of the vertebral column, the *right renal vein* is much shorter than the left, and it is consequently liable to be torn away from the vena cava during the manipulations necessary in excision of the right kidney. The *left renal vein* lies behind the pancreas, and crosses in front of the aorta and behind the superior mesenteric artery. It receives the left suprarenal and the left spermatic veins (p. 268).

Movable Kidney.—Under normal conditions the kidney cannot be palpated, although it moves slightly with respiration. Sometimes the movement may become so increased in amount as to give rise to distressing symptoms from kinking of the ureter. When this condition is suspected, the patient should first be examined in the recumbent and then in the semi-recumbent or in the sitting posture. The surgeon places one hand in the interval between the last rib and the iliac crest and the other on the anterior abdominal wall, and the patient is then instructed to take a deep breath. As the abdominal wall collapses with expiration, the surgeon gently presses the tips of his fingers in below the costal margin and attempts to catch the kidney between his two hands. In minor degrees of mobility only the lower pole of the kidney may be felt, as it slips upwards from the tips of the fingers, but when the condition is marked, the whole kidney may be caught, or the fingers may even be made to meet above its upper pole.

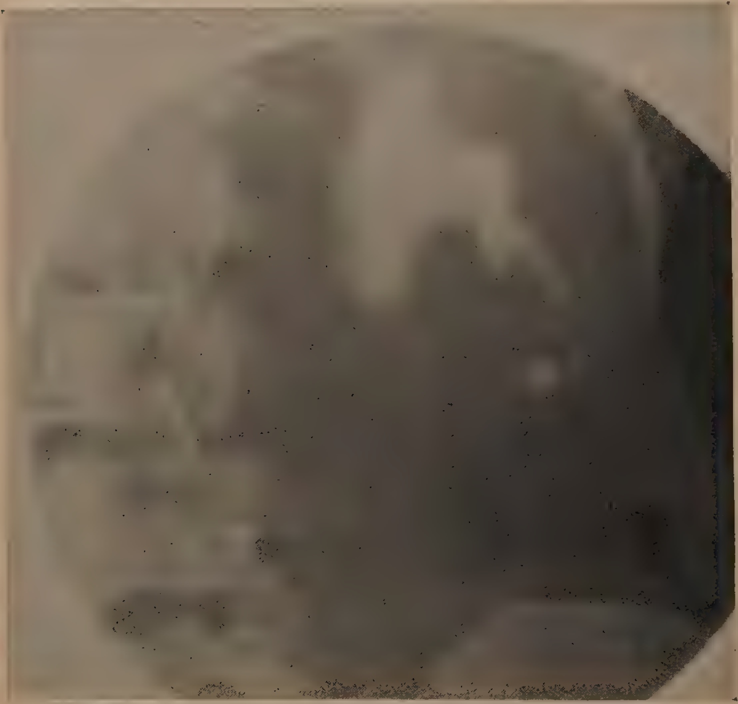

FIG. 110.—Calculus in the Renal Pelvis. The twelfth rib is almost entirely obscured by the large calculus. A smaller calculus is present in the lower pole of the kidney.

The right kidney is more often at fault than the left, and a movable right kidney must not be confused with an enlarged gall-bladder (p. 317). On either side an ovarian cyst which possesses a long pedicle may be mistaken for a movable kidney. This is owing to the fact that the surgeon, on examination, is able to manipulate the tumour into the position which the kidney normally occupies. When a movable kidney has been replaced in this way, it tends to maintain its position, but an ovarian cyst soon sinks down again towards the pelvis.

The **Ureter** is about ten inches long. It commences at the renal pelvis and is somewhat constricted at its point of origin. It descends on the anterior surface of the psoas major, which separates it from the tips of the transverse processes of the lumbar vertebræ, and enters the pelvis by crossing the bifurcation of the common iliac, or the external iliac artery near its commencement.

On the right side, the ureter lies behind the peritoneum of the right infra-colic compartment, but before it enters the pelvis it is crossed by the root of the mesentery and the terminal part of the ileum. At its upper end it lies behind the second and third parts of the duodenum; between the latter and the root of the mesentery, the right colic, spermatic, and ileo-colic vessels cross its anterior surface and separate it from the peritoneum (Fig. 88). On account of these relations the lumbo-ilio-inguinal route (p. 278) for exposure of the ureter is to be preferred to the trans-peritoneal route.

On the left side, the ureter lies behind the peritoneum of the left infra-colic compartment, and as it enters the pelvis it is crossed by the pelvic meso-colon. The left colic, spermatic, and sigmoid vessels cross its anterior surface (Fig. 107).

The *blood-supply* of the ureter is derived from the renal, spermatic, superior, and inferior vesical arteries. These branches anastomose freely with one another, and as a result large segments of the ureter can be freed without any subsequent sloughing.

The *nerve-supply* of the renal pelvis and the ureter is derived from the eleventh and twelfth thoracic and the first and second lumbar segments. In *renal colic* strong waves of contraction pass down the ureter, and the pain is successively referred to the skin areas supplied by these segments. When the calculus is situated in the renal pelvis, the pain begins in the loin in the area supplied by T. 11, and passes obliquely round the lower part of the abdominal wall affecting the areas supplied by T. 12 and L. 1 (ilio-hypogastric). Sometimes the pain shoots into the testis, and testicular hyperæsthesia may persist after the attack. This is due to the sensory branch which the external spermatic (genital branch of genito-crural) nerve (L. 1 and 2) gives to the tunica vaginalis testis (Mackenzie). At the same time, the afferent impulses from the strongly contracting ureter may excite a viscero-motor reflex (p. 255). The lower portions of the lateral abdominal muscles become rigid, and the cremaster muscle may contract and draw the testis up towards the subcutaneous inguinal ring. All the muscles affected are innervated from the same segments as supply the skin areas over which the pain is felt. The viscero-sensory reflex may also affect the lumbo-inguinal nerve (crural branch of genito-crural) and the posterior rami of the upper lumbar nerves so that pain is experienced in the front of the thigh and in the buttock.

THE PELVIS.

The Pelvis Minor (True Pelvis).—The walls of the pelvis consist of three layers: (1) a bony and ligamentous stratum, (2) a muscular stratum, and (3) a fascial stratum.

1. The *osseous circle*, formed by the sacrum, the coccyx, and the hip bones, is strengthened by the sacro-tuberous and sacro-spinous ligaments (great and small sacro-sciatic), which connect the sacrum and coccyx with the ischium. In the pubic arch this layer is represented by the inferior fascia of the urogenital diaphragm (anterior layer of triangular ligament).

2. The *muscular layer* consists of: (*a*) the obturator internus, which arises from the side wall of the pelvis and passes through the lesser sciatic foramen (p. 424); (*b*) the piriformis, which arises from the front of the sacrum and passes through the greater sciatic foramen; and (*c*) the sphincter of the membranous urethra (compressor urethræ), which assists in filling the gap between the inferior rami of the pubes.

3. The fascia which covers these muscles is termed the *parietal pelvic fascia*. It is continuous above with the fascia lining the abdomen and is attached below to the margins of the inferior pelvic aperture.

The large nerves of the lumbo-sacral and sacro-coccygeal plexuses lie between the muscular and fascial strata, but the large blood-vessels lie under the peritoneum internal to the fascia, and, with the exception of the obturator artery (p. 416), pierce it as they leave the pelvis through the various foramina. The points at which they pass through the fascia are the sites of pelvic herniæ.

Fractures of the Pelvis are usually caused by severe crushing, and they occur at the weakest areas of the bony ring, namely, the pubic and ischial rami, where they bound the obturator foramen, and the sacrum, along the line of the sacral foramina. Rectal or vaginal examination will often disclose the extent of the fracture and may assist the surgeon to obtain the correct alignment of the displaced fragments. Serious complications arise if the sharp broken edges wound any of the pelvic viscera.

The **Parietal Pelvic Fascia** covers the piriformis, the obturator internus, and the sphincter of the membranous urethra. The *obturator internus* arises from the posterior part of the ilio-pectineal line, and over this area the parietal pelvic fascia is directly continuous with the abdominal fascia covering the psoas major (p. 275). More anteriorly, the upper border of the obturator internus gradually sinks to a lower level and carries the parietal pelvic fascia with it; so that the inner surface of the superior ramus of the pubis is left uncovered by fascia or muscle. Opposite the obturator foramen, the fascia is carried over the upper border of the obturator internus and blends with the upper margin of the obturator membrane. In the region of the pubic arch it forms the *superior fascia of the urogenital diaphragm* (*deep layer of triangular ligament*) (Fig. 115), and its upper border blends with the upper border of the inferior fascia of the urogenital diaphragm (p. 382), leaving a small interval below the pubic symphysis for the passage of the dorsal vein of the penis.

The lower margin of the parietal pelvic fascia blends, in front, with the central point of the perineum, the free edge of the inferior fascia of the urogenital diaphragm and the fascia of Colles (p. 380); posteriorly, it is attached to the sacro-tuberous ligament and the ischial tuberosity.

The **Pelvic Diaphragm** stretches across the cavity of the pelvis, dividing it into an upper part, the pelvis proper, and a lower part, which is dealt with under the Perineum (p. 377). It is formed by the *two levatores ani* and *coccygei*, with the fascia covering them, but it is incomplete, as gaps are left for the passage of the anal canal and the urethra and, in the female, for the vagina also.

The *Levator Ani* has a linear origin from the side wall of the pelvis. Its posterior fibres are attached to the ischial spine; the intermediate fibres arise from the parietal pelvic fascia along a line extending from the ischial spine to the anterior border of the obturator foramen. The anterior fibres arise from the pelvic surface of the body of the pubis above the level of the parietal pelvic fascia, but they do not extend as far as the symphysis.

The posterior fibres pass medially and are inserted into the coccyx. In front of that point the muscles of the two sides meet in a median raphe and form a muscular sling, which supports the lower end of the rectum. The anterior fibres (*levator prostatæ*) pass backwards lateral to the prostate, which separates them from the muscle of the opposite side, and they extend downwards to the central point of the perineum and the outer surface of the anal canal. The succeeding fibres pass backwards lateral to the prostate and meet the corresponding fibres of the opposite side behind the upper end of the anal canal (*pubo-rectalis*). In the male, these fibres form a sphincter for the ano-rectal junction; in the female, they act also as a sphincter of the vagina.

Its *nerve-supply* is derived from the perineal division of the internal pudendal (S. 2, 3, 4) and directly from S. 3 and 4.

The *Coccygeus* is a small muscle which overlaps the posterior border of the levator ani. It extends from the ischial spine to the sides of the sacrum and coccyx, and helps to complete the pelvic floor.

The levator ani and the coccygeus constitute a muscular floor for the pelvis, and, like the muscles of the abdominal walls, they play an important part in retaining in place the abdomino-pelvic viscera. Further, active contraction of the levator ani coincident with contraction of the muscles of the abdominal walls and the diaphragm increases the intra-abdominal pressure and so assists in defæcation, parturition, etc.

The **Visceral Pelvic Fascia** is continuous with the fine layer of fascia which covers the pelvic surfaces of the levatores ani and the coccygei. Opposite the pubic symphysis, where the two levatores leave a gap, the fascia forms a continuous sheet from side to side. It is very weak in the middle line, but is specially thickened at each side, where it extends backwards to the prostate and the bladder, forming the *true pubo-prostatic ligaments* (*anterior pedicles of the bladder*). Elsewhere, its circumferential attachment corresponds to the linear origin of the muscles of the pelvic diaphragm.

When it is traced inwards from the sides, it is found to be in contact with the various pelvic viscera, which it provides with fibrous coverings. On account of this relationship the visceral pelvic fascia is described as consisting of *rectal*, *recto-vesical*, and *vesical portions*.

Anteriorly the visceral pelvic fascia is specially thickened around the pudendal plexus of veins (p. 368) and forms a strong fibrous sheath for the prostate.

The **Pelvic Peritoneum** is separated from the pelvic diaphragm by the pelvic viscera and blood-vessels. It covers the front and sides of the upper two-thirds of the rectum (p. 372) and is then reflected forwards on to the upper part of the posterior surface of the bladder, forming the floor of the recto-vesical fossa. It covers the superior surface of the bladder and is reflected from its apex on to the anterior abdominal wall.

The **Urinary Bladder** occupies the anterior part of the pelvic basin and lies immediately behind the pubes. When empty it is somewhat pyramidal in shape, with an apex, a base, a superior, and two infero-lateral surfaces.

The **apex** of the bladder is directed forwards and upwards and is in contact with the pubic symphysis. An impervious fibrous cord, known as the *urachus* (p. 385), passes upwards from the apex to the umbilicus in the extra-peritoneal fat.

The **base** or posterior surface is directed backwards and slightly downwards towards the rectum. It is roughly triangular in shape ; the inferior angle is truncated and corresponds to the internal orifice of the urethra, while the supero-lateral angles are joined by the ureters. In the middle line the two ductus deferentes lie side by side in apposition with this surface and separate the seminal vesicles from one another (Fig. 111). These parts of the genital tract are embedded in visceral pelvic fascia and intervene between the basal surface of the bladder and the rectum. A small interval, however, exists between the ductus deferentes near the upper border, and it slightly increases in size as the bladder becomes distended. Through this area the trochar was passed in puncture of the bladder by the old-fashioned rectal route.

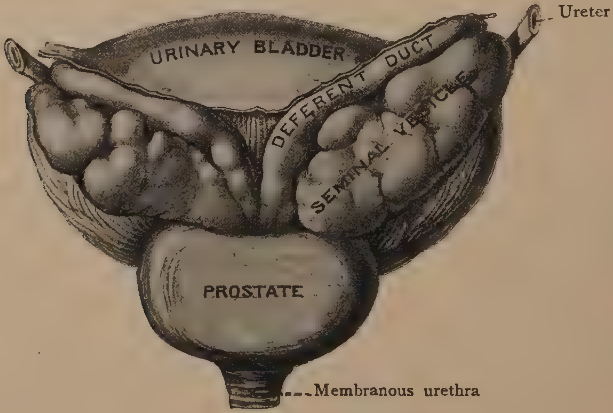

FIG. 111.—Basal aspect of Bladder, Seminal Vesicles, and Prostate, hardened by formalin injection.

The **superior surface** is entirely covered by peritoneum and is related to coils of small intestine or pelvic colon. Along its lateral borders the peritoneum is reflected on to the pelvic walls as the so-called lateral false ligaments of the bladder.

The **infero-lateral surfaces** are related in front to the bodies of the pubes and the retro-pubic pad of fat. Posteriorly they are in contact with the upper parts of the obturator internus and levator ani muscles.

The **neck** of the bladder is situated where the infero-lateral and posterior surfaces meet one another. It is pierced by the urethra and is partly continuous with the prostate.

When the bladder *distends,* it becomes more or less ovoid in shape. The neck and posterior surface are not much affected but the infero-lateral and superior surfaces become greatly stretched, and the upper part of the bladder comes to lie in the abdomen. The apex passes backwards as the bladder ascends and the urachus draws a fold of peritoneum backwards with it. The upper part of the anterior aspect of the distended bladder peels the peritoneum off the anterior abdominal wall and becomes covered by it, so that a coil of gut may come to intervene between this part of the bladder and the surface. Below, however, the lower part of the anterior aspect of the bladder comes into direct contact with the abdominal wall, no peritoneum intervening. In *aspirating* the over-distended bladder suprapubically, the surgeon takes advantage of this alteration in the disposition of the peritoneum, and in the operation of suprapubic cystotomy the same condition is obtained by distending the bladder artificially.

In the infant, the bladder occupies a higher position than it does in the adult owing to the smaller relative size of the pelvis and the greater relative size of the bladder itself. The internal orifice of the urethra lies almost on a level with the upper border of the pubic symphysis, and *most of the bladder is situated in the abdomen*. This difference must be borne in mind when opening the abdomen in the infant, and care should be taken to see that the bladder is evacuated before making an incision in the lower part of the anterior abdominal wall.

The *retro-pubic pad of fat* occupies the space which is bounded in front by the symphysis pubis, behind by the bladder, and below by the true pubo-prostatic ligaments. In extra-peritoneal rupture of the bladder the extravasated urine collects temporarily in this space (p. 382).

Supra-Pubic Cystotomy is commonly performed for the removal of calculi, tumours, and soft, enlarged prostates capable of easy enucleation. The bladder is emptied, and then filled with warm boracic lotion as a preliminary measure, its capacity having been estimated prior to anæsthesia so as to exclude the risk of over-distension. In this way the bladder is brought into direct contact with the lower part of the anterior abdominal wall, no peritoneum intervening (*vide supra*). A *transverse incision*, about four inches long, is made a little above the pubes. This passes through the skin and fasciæ and exposes the linea alba and both rectus sheaths. A *vertical incision* is made in the linea alba, and the two recti are retracted. If satisfactory access is not obtained, the muscles may be elevated from their pubic attachments so that they can be more widely separated.

The fascia transversalis is divided and the bladder is exposed in the extra-peritoneal fat. The fingers are then passed upwards until the line of peritoneal reflection is met, and the peritoneum is then further elevated from the bladder. In order to prevent the bladder from collapsing into the pelvis when it is incised, two retention sutures are passed through its wall and are held by an assistant during the operation. The bladder may now be incised, and the calculus, tumour, etc., removed.

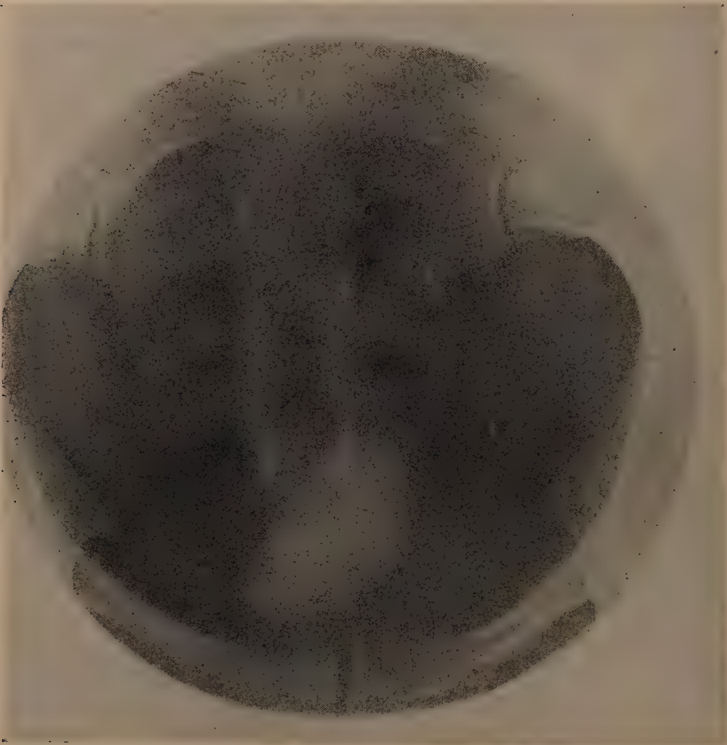

FIG. 112.—Vesical Calculus, Antero-posterior View. Observe the positions of the calculus and the ischial spines relative to the sacrum.

The **muscular coat of the bladder** is very strongly developed. Near the neck the outer fibres become continuous with the muscular tissue of the prostate; the intermediate fibres are increased in number and form the sphincter vesicæ internus; the inner layer becomes continuous with the longitudinal muscular coat of the urethra.

The **mucous lining of the bladder** is not so elastic as the muscular coat, and is thrown into rugæ when the bladder is empty. This is permitted by the laxity of the submucosa; but over a triangular area which corresponds to the basal surface, the mucous coat is smooth and firmly adherent to the muscular wall. This area is referred to as the *internal trigone*: its superior angles correspond to the openings of the ureters, and its inferior angle to the internal orifice of the urethra, which is 1½ inches from the opening of either ureter. The ureters pierce the bladder wall very obliquely, and when the intra-vesical pressure is increased as the bladder fills, this arrangement provides a valve-like action, which prevents a reverse flow towards the kidneys. The ureteral openings are about two inches apart and are connected by a ridge of mucous membrane called the *inter-ureteric bar*.

In *hypertrophy of the muscular coat*, to overcome the obstruction caused by stricture of the urethra, prostatic enlargement, etc., small pockets of mucous membrane may be formed in the intervals between the bands of enlarged fibres. These loculi sometimes form distinct diverticula, and they tend to retain urine, which decomposes and gives rise to calculus formation. The presence of incarcerated stones in the bladder wall can be accounted for in this way.

The *Arteries* of the bladder are derived from the hypogastric (internal iliac) artery by means of three paired vessels, the superior, middle, and inferior vesical arteries.

Together with the ureter, lymphatics, and nerves, the arteries and veins of each side are embedded in a sheet of visceral pelvic fascia, which passes forwards and medially to the lateral border of the posterior surface of the bladder and constitutes its *posterior pedicle*.

The vesical arteries supply the bladder, the seminal vesicles, the prostate and the terminal parts of the ureters. In addition the superior vesical usually gives off a special branch to the ductus deferens (p. 261).

The *vesical veins* join the pudendal (prostatic) plexus (p. 370), from which two or three large veins issue in the posterior pedicle of the bladder to join the hypogastric vein.

The *nerve-supply* of the bladder is derived entirely through the sympathetic. Some of the fibres come from the twelfth thoracic and first lumbar segments; the others arise from the second and third, or third and fourth sacral segments, and are restricted to the basal surface and the trigone. On account of the different segments involved, pain referred from the bladder is felt in two different regions. A vesical calculus irritates the trigone, and the pain is referred to the perineum and the penis (S. 2, 3, and 4). On the other hand, pain due to over-distension or caused by strong contraction of the muscular wall, such as occurs at the end of micturition in cases of vesical calculus, is usually referred to the lower part of the anterior abdominal wall (T. 12, L. 1).

In the presence of vesical calculi or ulcers of the bladder wall, the centres for micturition in the spinal medulla become hypersensitive, and frequency of micturition results.

The **Pelvic Part of the Ureter** is closely related to the peritoneum. It crosses the brim of the pelvis in front of, or a little lateral to, the bifurcation of the common iliac artery, and descends in front of the hypogastric (internal iliac) artery, which separates it from the posterior wall of the pelvis and the great nerve trunks. As it approaches the base of the bladder, it curves medially and enters the posterior pedicle. Here it is related to the superior vesical artery, which lies above it, and the other vesical arteries and veins, which lie below it. Just before entering the bladder (p. 362), the ureter is crossed latero-medially and on its superior aspect by the ductus deferens, which intervenes between it and the peritoneum.

This part of the ureter is supplied by the vesical arteries.

Impacted calculi in the pelvic part of the ureter are usually found (1) at the pelvic brim, on a level with the first sacral vertebra, or (2) at the point of entrance into the bladder, on a level with the first coccygeal vertebra, because the lumen of the tube is distinctly narrower at these two points. When a radiogram shows a shadow which might be an ureteral calculus, its horizontal level is of as great importance as its vertical plane as an aid to differential diagnosis.

The *surgical approach* for the removal of an impacted ureteral calculus may be either retro-peritoneal or infra-peritoneal.

Calculi impacted near the pelvic brim are best approached by the retro-peritoneal route (p. 278).

Infra-peritoneal Route.—In order to obtain access to the terminal part of the ureter, an oblique incision, which is directed downwards and medially, is made through the lower part of the anterior abdominal wall (Fig. 71). In its medial two-thirds this incision crosses the rectus muscle below the level of the linea semicircularis (of Douglas). The aponeurosis of the external oblique is divided, and the fleshy fibres of the internal oblique and transversus are separated, in the lateral part of the wound, whilst medially the anterior wall of the rectus sheath is divided and the muscle is retracted in a medial direction. The transversalis fascia is now exposed, and the inferior epigastric artery, which may be ligated if necessary, is found on its surface in the medial part of the wound.

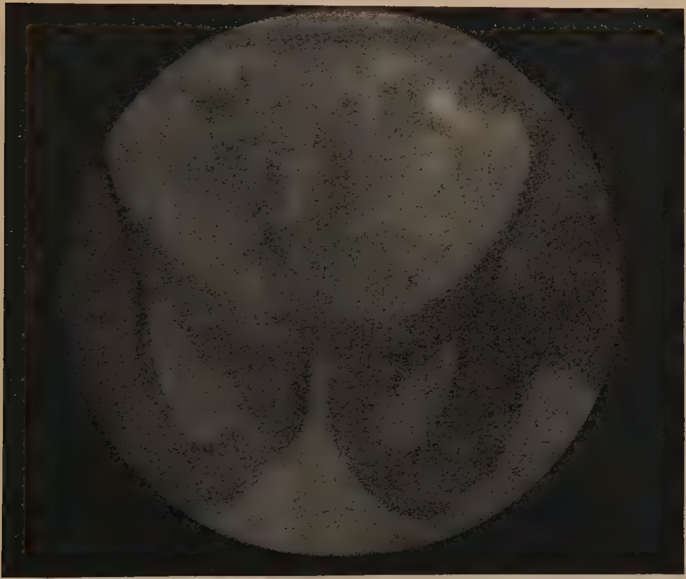

FIG. 113.—Radiogram showing the presence of phleboliths in the pelvis.

The fascia transversalis is torn through in the neighbourhood of the bladder, and the peritoneum is retracted upwards and medially. In this way the abdominal viscera are kept out of the field of operations and more space is obtained. When the peritoneum is elevated, the external iliac vessels are exposed in the posterior part of the wound, and the ductus deferens is seen in front, as it descends to reach the seminal vesicles (p. 362). In this part of its course the ureter is not adherent to the peritoneum, but is closely related to the structures on the pelvic wall. The *superior vesical artery* forms a convenient guide, since it lies anterior to the ureter. As a small calculus, impacted in the terminal portion of the ureter, may be extremely difficult to feel, an assistant pushes the bladder upwards by means of a finger in the rectum. The surgeon then presses the ureter against the resistance thus afforded, and determines the precise position of the stone.

Calculi impacted in the vesical orifice of the ureter may be removed trans-vesically (cf. removal of gall-stones impacted in ampulla of Vater, p. 320).

The **Prostate** consists chiefly of plain muscle fibres and glandular tissue, surrounded by a *fibrous capsule*. The muscle fibres are directly continuous with the external stratum of the muscular coat of the bladder. The prostate possesses a strong *fibrous sheath*, which is formed anteriorly and on each side by the connective tissue in which the prostatico-vesical plexus of veins is placed. Posteriorly, the sheath is formed by the recto-vesical septum (fascia of Denonvillers), which is non-vascular and is formed in fœtal life by the adhesion of the peritoneal layers which originally descend to the central point of the perineum. This septum is firmly adherent inferiorly to the posterior aspect of the prostate, but it can easily be separated from the rectum, by breaking down the loose cellular tissue which intervenes between them.

In size and shape the prostate resembles a chestnut. Its *base* is directed upwards and is partly continuous with the neck of the bladder; its apex is directed downwards and rests on the superior fascia of the urogenital diaphragm. The *posterior surface* is in contact with the rectum and can readily be palpated on rectal examination. The *lateral surface* is crossed by the anterior border of the levator ani and can also be examined from the rectum.

The prostate encloses the first part of the urethra, which pierces its base, traverses its substance, and emerges a little above its apex. It is also pierced by the common ejaculatory ducts (p. 371).

A well-marked groove separates the prostate from the bladder externally. At this level the prostatic sheath contains in its walls the *pudendal* (*prostatico-vesical*) *plexus of veins*, which receives the dorsal vein of the penis (p. 391), and tributaries from the bladder and prostate. The prostatic veins cross the potential interval between the capsule and the sheath to reach the plexus, and are consequently torn in prostatectomy. (Compare this arrangement with the course of the thyreoid veins, p. 172.)

The pudendal plexus terminates in the large veins which have already been mentioned in connection with the posterior pedicle of the bladder (p. 365).

Hypertrophy of the Prostate usually involves the glandular tissue, and may be confined to the " middle lobe " ; but the whole prostate may become enlarged. The dense, unyielding character of the sheath limits the growth in antero-posterior and lateral directions, but the neck of the bladder offers little resistance to upward extension. As a result the prostatic tissue projects into the bladder through the internal sphincter and forms a collar-like elevation around the internal urethral orifice. The muscular tissue which connects the prostate and the bladder is stretched and thinned out, so that few or no fibres are encountered by the surgeon in prostatectomy (p. 370), and the tumour is exposed as soon as the mucous membrane over it has been torn through.

Owing to the direction of growth the prostatic urethra becomes increased in length from 1¼ to 2 or 2½ inches, and at the same time its forward concavity becomes proportionately greater.

The so-called " middle lobe " of the prostate is that part which intervenes between the ejaculatory ducts (p. 371) and the urethra. Its upper surface lies under the mucous coat of the trigone of the bladder, immediately behind the internal urethral orifice, and when well marked produces a slight elevation known as the *uvula vesicæ*. When hypertrophy affects the middle lobe only, the prostate is apparently normal on rectal examination. In these cases the enlarged uvula seriously hinders the escape of urine through the internal urethral orifice and constitutes one of the worst forms of urinary obstruction.

Effects of Prostatic Hypertrophy.—The upward growth of the prostate weakens the internal sphincter of the bladder so that urine enters the urethra more easily and the desire to micturate is more frequent.

A pouch gradually forms behind the collar-like elevation which surrounds the internal urethral orifice, and the urine which it contains can only be evacuated by straining. As the tumour increases in size, the pouch becomes deeper and attempts to evacuate it merely crush down the projection over the orifice of the urethra. The urine in this part of the bladder cannot be passed, and is termed "residual urine." The straining causes hypertrophy of the muscular wall, and for a time this may assist micturition. Ultimately, however, the increasing amount of residual urine leads to dilatation of the bladder, and urine can only be passed by the contraction of the abdominal muscles. The quantity passed at one time is necessarily small, so that the bladder remains constantly distended. This condition may come on very gradually, and the patient, being totally unaware of its nature, only complains of symptoms which are referable to chronic auto-intoxication.

Attacks of prostatic congestion are followed by complete retention of urine and still further dilatation of the bladder, which may never regain its muscular tone. The rapid evacuation of a greatly distended and dilated bladder by the passage of a catheter may be followed by severe hæmorrhage, as the weakened muscular wall, when relieved of its internal pressure, is unable to contract, and the vessel-walls, being unsupported, give way.

Supra-Pubic Prostatectomy.—A catheter is first passed into the bladder, and the viscus is then opened by the method outlined on p. 363. The surgeon inserts his finger, and guided to the internal urethral orifice by the instrument, he scrapes through the mucous coat overlying the prostate with his finger-nail. At the same time the surgeon may pass the index finger of his free hand, suitably protected, into the rectum and use it as a guide and support for his manipulations inside the bladder. Owing to the thinning out of the muscular tissue (p. 369) the tear in the mucous coat at once exposes the prostate. When the enlargement is due to an adenoma, the true prostatic tissue is thinned out and compressed against the sheath. Enucleation is comparatively easy and the pudendal plexus of veins is not in danger. On the other hand, if the enlargement of the prostate is due to hypertrophy of its fibrous tissue, the whole gland has to be enucleated from its sheath. The surgeon endeavours to thrust his finger through into the interval between the capsule and the sheath. This interval is defined by sweeping the finger first round one side of the prostate and then round the other. In the process the prostatic veins are torn through as they pass outwards to join the pudendal plexus. The prostate is now only fixed by the distal end of the prostatic urethra, and this is torn across as it pierces the urogenital diaphragm.

If the surgeon fails to define the interval between the capsule and the sheath and penetrates the latter with his finger-nail, severe hæmorrhage results from the thin-walled veins of the pudendal plexus and its vesical tributaries. The condition is accentuated if the surgeon continues to attempt enucleation with his finger in the wrong stratum.

Drainage is obtained by a wide supra-pubic tube, but in the presence of cystitis some surgeons make use of a perineal drain in addition. A pair of long forceps is inserted through the supra-pubic wound into the cavity of the prostatic sheath and cut down on in the perineum. A tube is then drawn upwards, and the whole cavity can be washed out thoroughly. An advantage of this additional drain is that it prevents absorption from the accumulation of septic urine and blood-clot in the raw area.

As a result of the removal of the prostate, the first part of the urethra is replaced by a fibrous sac—the prostatic sheath. The neck of the bladder opens into it above and the urethra opens out from it below. This cavity soon collapses and its walls gradually become lined by mucous membrane, which grows upwards from the torn urethra and downwards from the bladder.

The **Seminal Vesicles** lie obliquely on the basal surface of the bladder; their upper extremities are widely separated and their lower extremities are close together. Posteriorly, they are related to the anterior surface of the rectum, and only visceral pelvic fascia intervenes. The upper, blind end of the seminal vesicle lies immediately under the floor of the recto-vesical peritoneal fossa and close to the termination of the ureter. Its lateral border is closely applied to the medial aspect of the posterior pedicle of the bladder, and its medial border is related to the ductus deferens (Fig. 111).

Inferiorly the seminal vesicle narrows to form the excretory duct, which joins the ductus deferens to form the common *ejaculatory duct.* The two ejaculatory ducts pass downwards and forwards through the substance of the prostate and open into the prostatic urethra close to the orifice of the prostatic utricle (p. 388).

The **Rectum** begins opposite the third piece of the sacrum as the direct continuation of the descending limb of the pelvic colon. It is about five inches long and curves downwards and forwards to a point a little above the apex of the prostate, where it bends sharply backwards and downwards, over the pubo-rectalis muscle (p. 360), to form the anal canal. The expanded lower part of the rectum is termed the ampulla and is better marked in the female than in the male.

In its upper third the rectum is clothed by peritoneum anteriorly and on each side; in its middle third it is only covered anteriorly; its lower third lies below the line of reflection of the peritoneum from the rectum to the bladder (p. 361) and is consequently devoid of any peritoneal covering (Fig. 115). The upper two-thirds of the rectum is related anteriorly to the coils of small intestine, or pelvic colon, which occupy the recto-vesical fossa and separate it from the bladder, and tumours of the pelvic colon may sometimes be palpated per rectum. In front of the lower third of the rectum lie the seminal vesicles, ductus deferentes and the prostate, embedded in visceral pelvic fascia (Fig. 115).

As it descends following the curvature of the sacrum and coccyx, the rectum exhibits three *lateral flexures*, the uppermost and lowermost being directed to the left and the middle one to the right. As a result, the rectum is not median in position but projects to the left side of the middle line. On the concavity of each bend, a crescentic fold, consisting of the mucous and circular muscular coats, projects within the lumen of the gut and stretches almost halfway round it. These folds are known as the *plicæ transversales recti* (*rectal valves*), and they serve to support the fæces and to prevent over-distension of the ampulla. Scybalous masses supported by the lowest fold, which lies at about three inches from the anus, can be reached by the tip of the finger on rectal examination, but, as they cannot be completely examined, care must be taken not to mistake them for a malignant tumour. The plicæ transversales recti can easily be seen on examination with the sigmoidoscope, the patient being placed in the knee-elbow position.

Posteriorly, the upper two-thirds of the rectum is in contact with the sacrum and coccyx in the median plane, and, on each side, overlaps the piriformis muscle and the nerves of the sacral plexus, from which, however, it is separated by the parietal pelvic fascia and its own covering of visceral pelvic fascia. When loaded, the rectum may exert pressure on the nerves, especially of the left side, and produce the painful symptoms of sciatica. The lower third of the rectum rests on the pelvic floor (p. 361) and is surrounded by the rectal layer of the visceral pelvic fascia.

The hypogastric (internal iliac) vessels and lymph glands and the ureters are related to the sides of the rectum, but the latter are only in contact with its wall when the gut is considerably distended.

Structure of the Rectum.—The submucous coat consists of very loose areolar tissue, and, as a result, the mucous coat may become prolapsed through the anus, following violent straining.

The circular muscular coat forms a complete covering for the gut but the longitudinal coat is arranged in two broad bands, which lie one on its anterior and the other on its posterior surface. The shortness of these bands, relative to the length of the mucous and circular muscular coats, accounts for the production of the lateral flexures of the rectum.

Some of the anterior longitudinal fibres turn forwards at the ano-rectal junction and end in the upper part of the central point of the perineum (Fig. 114). They constitute the superior recto-urethralis muscle (of Roux). The inferior recto-urethralis muscle is formed by longitudinal fibres which ascend on the anterior aspect of the anal canal and turn forwards into the lower part of the central point of the perineum. Section of these muscles is an important step in the operations of prostatectomy and excision of the rectum by the perineal route (p. 386).

The **Anal Canal**, which is about one and a half inches long, passes downwards and backwards from the rectal ampulla to the anus. Except during defæcation, its walls are kept in apposition by the action of the levatores ani and sphincter muscles. The sides of the anal canal are in relation to the elastic pads of fat which occupy the ischio-rectal fossæ (p. 377). Anteriorly, the anal canal is related to the central point of the perineum, the membranous part of the urethra and the bulb of the penis (Fig. 115). The surgeon takes advantage of this relation when he is negotiating a bougie through a difficult stricture of the urethra. By inserting the forefinger of his left hand into the rectal ampulla, he can control the point of the instrument and can recognise at once if it is making a "false passage." Further, in supra-pubic prostatectomy, the enucleating finger of the right hand within the bladder will be greatly assisted if the surgeon passes his left forefinger into the ampulla of the rectum.

The **muscular coat** of the anal canal is very strongly developed. The circular fibres of the rectum are continued downwards to form the *internal sphincter*, which clothes the upper two-thirds of the canal. The levatores ani lie external to the internal sphincter and some of their fibres are prolonged downwards in the wall of the anal canal. The external sphincter lies very superficially, and is attached to the tip of the coccyx behind and to the central point of the perineum in front.

The **submucous coat** of the anal canal is very lax and contains tributaries of the hæmorrhoidal veins.

The **mucous coat** of the anal canal is loosely attached to the muscular wall and, in its upper part, is thrown into a number of vertical folds, termed the *rectal columns* (*of Morgagni*). These are united at their lower ends by small semilunar folds, which are termed the *anal valves*. Ball suggests that anal fissure is produced by the tearing downwards of one of the anal valves by a scybalous mass.

The line formed by the anal valves, sometimes termed the *pectinate line*, marks the junction between the columnar epithelium of the intestinal canal and the scaly epithelium of the skin, and therefore indicates the site of the embryonic anal membrane (p. 384).

Blood-supply of the Rectum and Anal Canal.—(1) The *superior hæmorrhoidal artery* (p. 345) descends in the root of the pelvic meso-colon and divides into right and left branches, which run downwards on the muscular coat of the rectum. They give off numerous branches, which pierce the muscular coat and supply the mucous membrane of the rectum and the upper part of the anal canal, anastomosing freely with one another and with the inferior and middle hæmorrhoidal arteries.

(2) The *middle hæmorrhoidal arteries* arise from the hypogastric arteries and are mainly distributed to the muscular coat of the rectum. As they approach the gut they are embedded in cellular tissue, which offers some resistance when the surgeon endeavours to drag down the rectum in the operation of excision (p. 386). This cellular tissue is termed by Ball the lateral ligament of the rectum.

(3) The *inferior hæmorrhoidal arteries* arise, on each side, from the internal pudendal in Alcock's canal (p. 377) and run downwards and medially across the ischio-rectal fossæ to reach the sides of the anal canal. They are distributed to the muscular wall of the anal canal and to the lower part of its mucous coat.

(4) The *middle sacral artery* arises from the abdominal aorta near its termination and runs downwards in the median plane on the anterior surface of the sacrum. It supplies a few twigs to the muscular coat of the rectum.

Veins of the Rectum and Anal Canal.—The *internal hæmorrhoidal plexus* lies in the submucous tissue of the anal canal, and by its means the superior, middle, and inferior hæmorrhoidal veins communicate with one another.

The *superior hæmorrhoidal* veins arise from the upper end of the plexus and pass upwards in the submucous coat of the rectum. About the middle of the rectum they pierce the muscular coat and unite to form a common trunk, which ascends in the pelvic mesocolon and ultimately becomes the inferior mesenteric vein (p. 323).

The *middle hæmorrhoidal* veins also arise in the internal hæmorrhoidal plexus and pierce the muscular coat of the anal canal. They run backwards on the upper surface of the levator ani and join the hypogastric (internal iliac) vein.

The *inferior hæmorrhoidal* veins join the internal pudendal vein.

The **anal veins** are arranged radially around the margin of the anus. They communicate with the internal hæmorrhoidal plexus and also with the inferior hæmorrhoidal veins. Excessive straining during the passage of large scybala may lead to rupture of one of the anal veins, and the extravasated blood gives rise to a small swelling at the muco-cutaneous junction, which is termed an *external hæmorrhoid*.

Varicosity of the veins of the internal hæmorrhoidal plexus constitutes the condition known as *internal hæmorrhoids*. This may be brought about by portal obstruction, whether hepatic or cardiac in origin, since the portal and systemic circulations communicate in the internal hæmorrhoidal plexus (p. 314). Further, the course taken by the superior hæmorrhoidal veins exposes them to marked obstruction during contraction of the muscular coat of the rectum and the downward passage of fæces. This obstruction, together with the absence of venous valves, acts as a predisposing cause of the condition. Internal hæmorrhoids may become prolapsed through the anus with each evacuation of the bowels or they may even protrude in the erect posture. Their constriction by the external sphincter gives rise to an acute attack of "piles," and may lead to areas of sloughing or actual gangrene.

Bleeding from internal hæmorrhoids is venous in nature and irregular in occurrence. On the other hand, bleeding from a malignant tumour of the rectum is arterial in nature and occurs with each act of defæcation.

In the operation for internal hæmorrhoids, the clamps or forceps should be applied parallel to the course of the vessels, *i.e.* in the long axis of the bowel, and special care should be taken to make sure that the vessels at the base of the pile are secured. If this is not done, considerable hæmorrhage may occur into the rectum with no outward sign until an enormous blood-clot is passed or the condition of the pulse attracts attention.

The **Nerve-Supply of the Rectum and Anal Canal** is mainly derived from S. 2, 3, and 4, through the pelvic splanchnics (p. 129). The nerves which supply the internal trigone of the bladder and the sphincter vesicæ internus are derived from the same source (p. 366). It is not surprising to find that interference with the rectum or anal canal produces reflex results in the bladder. For example, retention of urine, due to spasm of the sphincter vesicæ internus, may follow operations on the anus or rectum. A similar result may be brought about by irritation of the cutaneous nerves of the perineum (S. 2, 3, and 4), *e.g.* following a long cycle ride.

Cutaneous branches are supplied by S. 2 and 3 to the back of the thigh and leg (p. 423), and may be the site of referred pain in irritative or inflammatory conditions of the rectum or pelvic colon.

The lower part of the anal canal, which is ectodermal in origin (p. 385), receives its nerve-supply from the inferior hæmorrhoidal nerve.

The **Lymph Vessels** of the rectum and anal canal, above the pectinate line, drain into lymph glands which lie on the posterior surface of the rectum and their efferents ascend along the superior hæmorrhoidal artery to end in the sacral and lumbar lymph glands.

From the lower part of the anal canal, the lymph vessels pass to the subinguinal lymph glands (p. 405). They reach their destination by two paths; some run antero-laterally across the urogenital triangle, and the others run postero-laterally round the lateral aspect of the thigh at about the level of the greater trochanter. From the inguinal group, efferents pass through the femoral (crural) ring to join the external iliac lymph glands.

Examination of the Rectum and Anal Canal.—After passing through the anus, the finger is at once grasped by the external sphincter, but may be gently advanced upwards and forwards for about one and a half inches, until it slips past the internal sphincter and enters the rectal ampulla. If the anus is found to be tightly contracted and very tender, anal fissure may be suspected, and further examination should be conducted under an anæsthetic.

Through the lowest part of the anterior wall of the rectal ampulla the bulbo-urethral glands (of Cowper) can be felt, when they are inflamed and enlarged. At a slightly higher level, the posterior surface of the prostate can be examined. The seminal vesicles, lying on the posterior surface of the bladder, can be recognised, when diseased, as nodular projections immediately above the prostate. About three inches from the anus, which is the average limit of reach, the finger-tip is in contact with the rectal wall just below the line of peritoneal reflection.

If the finger is rotated laterally, the medial aspect of the pelvic wall may be examined, and, postero-laterally, the hypogastric (internal iliac) lymph glands can be made out when they are enlarged.

With the pulp of the finger directed backwards, the lowest *plica transversalis recti* (*rectal valve*) may be felt, and enlarged lymph glands on the anterior surface of the sacrum can be recognised by pressing them against the bone. When the patient is told to strain, the part of the bowel which lies just out of reach in the passive condition can be " threaded " on the finger and examined.

In the " ballooned " condition of the rectum, the walls of the gut cannot be made out after the finger has passed through the internal sphincter.

In the female, the os uteri can be palpated through the anterior wall of the rectum, and the uterus itself may be felt when retroflexed.

THE PERINEUM.

The **Ischio-Rectal Fossa** lies between the lower part of the obturator internus and the levator ani. Posteriorly, it is limited by the glutæus maximus and the sacro-tuberous ligament; anteriorly, it extends forwards to the urogenital diaphragm. Above, it is shut off from the pelvis by the attachment of the levator ani to the parietal pelvic fascia (Fig. 114). The sloping medial wall of the fossa is formed by the levator ani as it clothes the anal canal and the lower part of the rectum.

After leaving the gluteal region (p. 422), the internal pudendal vessels enter Alcock's canal, which lies in the fascia on the lateral wall of the ischio-rectal fossa. They give off the inferior hæmorrhoidal vessels, which pass downwards and medially across the fossa to supply the anal canal. The vessels are accompanied by the inferior hæmorrhoidal nerve, which arises from the pudendal and terminates in the external sphincter.

Ischio-rectal abscesses originating in connection with some small ulcer, laceration of the rectal sinuses, etc., may rupture through the skin and give rise to an external sinus ; or they may rupture into the anal canal, in which case an internal sinus is formed. The orifice of an internal sinus is generally found at the pectinate line (p. 374), *i.e.* the track of the sinus lies below the level of the levator ani and longitudinal muscular coat of the gut. An ischio-rectal abscess may rupture in both directions and so give rise to a complete fistula. As the whole fistula lies below the internal sphincter, it is only necessary to divide the external sphincter, the movements of which tend to keep the fistula open. This should be carried out radially from the anal margin, *i.e.* at right angles to its fibres, and in one place only, otherwise the muscle may fail to unite. In the examination of a case of *fistula in ano*, it is advisable to pass a probe into the fistula before inserting the finger into the anal canal, as this process may induce spasm of the external sphincter and so make the passage of a probe a matter of greater difficulty. Sometimes the mucous membrane is undermined for some

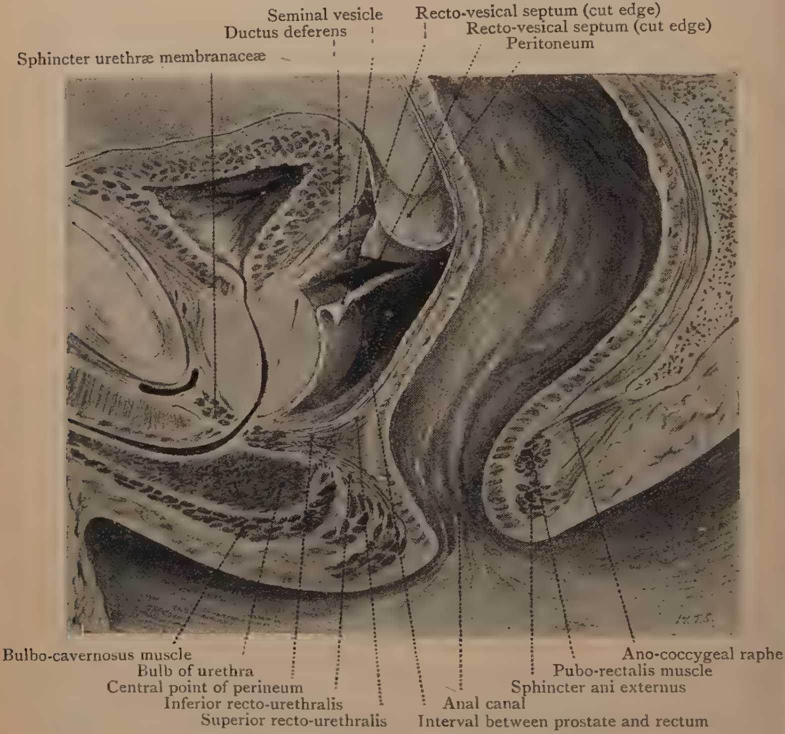
Seminal vesicle
Ductus deferens
Recto-vesical septum (cut edge)
Recto-vesical septum (cut edge)
Peritoneum
Sphincter urethræ membranaceæ
Bulbo-cavernosus muscle
Bulb of urethra
Central point of perineum
Inferior recto-urethralis
Superior recto-urethralis
Ano-coccygeal raphe
Pubo-rectalis muscle
Sphincter ani externus
Anal canal
Interval between prostate and rectum

FIG. 114.—Median Sagittal Section of Male Pelvis to show the Relations of the Pelvic Fascia.

distance above the internal opening of the fistula, and the point of the probe may be felt separated from the finger by the mucous coat alone.

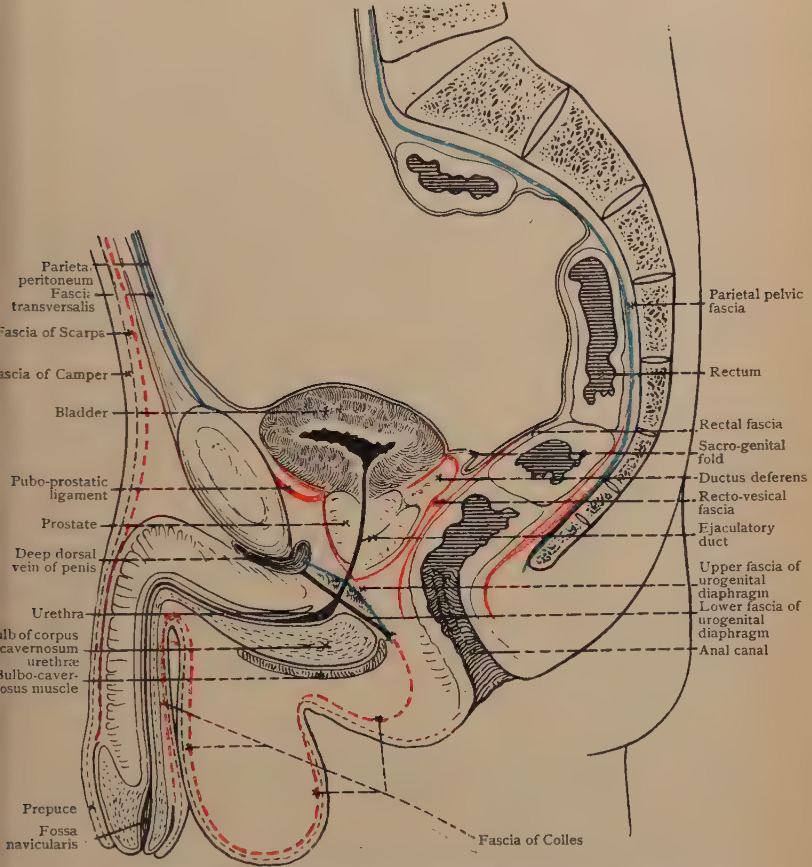
Parieta. peritoneum
Fasci: transversalis
ascia of Scarpa
ascia of Camper
Bladder
Pubo-prostatic ligament
Prostate
Deep dorsal vein of penis
Urethra
lb of corpus cavernosum urethræ
ulbo-cavernosus muscle
Prepuce
Fossa navicularis
Fascia of Colles
Parietal pelvic fascia
Rectum
Rectal fascia
Sacro-genital fold
Ductus deferens
Recto-vesical fascia
Ejaculatory duct
Upper fascia of urogenital diaphragm
Lower fascia of urogenital diaphragm
Anal canal

FIG. 115.—Diagram of Median Section through Male Pelvis, showing the arrangement of the Peritoneum, the Endopelvic Fascia and the Fascia of Colles.

Abscesses arising above the levator ani, either in connection with the pelvic organs or diseased bone, sometimes pierce the muscle and enter the ischio-rectal fossa from above.

The **Pudendal Nerve** arises from the sacral plexus (S. 2, 3, and 4), and accompanies the internal pudendal vessels through the greater sciatic foramen (p. 422). It then passes downwards on the dorsal surface of the sacro-spinous (small sacro-sciatic) ligament and enters the posterior part of the ischio-rectal fossa through the lesser sciatic foramen. In Alcock's canal, it gives off the *inferior hæmorrhoidal* and divides into the *perineal nerve* and the *dorsal nerve of the penis*.

The **Urogenital Triangle** extends from the pubic symphysis to the central point of the perineum, which lies half an inch anterior to the anus, and it is limited laterally by the pubic arch.

The *superficial fascia* over this region consists of two strata. The first is a fatty layer, continuous with the general fatty covering of the body. The second, the deeper layer, is denser and more membranous in character. Above, it is continuous with the fascia of Scarpa (p. 244), which is continued downwards from the abdomen on each side to be attached to the fascia lata of the thigh just distal to the inguinal (Poupart's) ligament. Between the two pubic tubercles, the fascia of Scarpa is carried down over the urogenital triangle, where it is termed the *fascia of Colles*. The latter encloses the penis, as in the finger of a glove, clothes the scrotum, and finally blends with the base of the urogenital diaphragm. Laterally, the fascia of Colles is attached to the fascia lata of the thigh from the pubic tubercle downwards and medially to the border of the pubic arch, and then along the latter to the tuber ischii.

The **Superficial Perineal Pouch** is a space which is bounded in front by the fascia of Colles, and behind by the urogenital diaphragm. It is closed inferiorly by the union of its two walls and laterally by their attachments to the pubic arch. Superiorly, however, it communicates freely with the cellular interval between the fascia of Scarpa and the anterior wall of the rectus sheath. The superficial perineal pouch contains the structures which form the root of the penis and the muscles which cover them (p. 381). It also contains the whole of the cavernous (spongy) portion of the urethra, and rupture of this portion of the urethra, whether from trauma or following stricture, leads to extravasation of urine into the pouch. This first affects the lowest part of the pouch, viz. between the neck of the scrotum and the base of the urogenital diaphragm, and then passes forwards and distends the scrotum (Fig. 115). The loose cellular tissue of the penis next becomes infiltrated, and the "ram's horn penis" is produced. Lastly, the extravasated urine passes upwards on to the anterior abdominal wall spreading laterally behind the fascia of Scarpa, and the attachment of the latter to the fascia lata prevents its downward spread into the thigh.

The **root of the penis** consists of the bulb and the two crura. The *bulb* is placed in the median plane and is closely attached to the inferior fascia of the urogenital diaphragm (anterior layer of triangular ligament). It is traversed by the urethra and its surface is completely covered by the *bulbo-cavernosus* (*ejaculator urinæ*) *muscle*, which serves to eject the last drops of urine or semen. The *crus penis* is firmly attached to the margin of the pubic arch and is covered by the *ischio-cavernosus* (*erector penis*) *muscle.* The two crura converge anteriorly and lie side by side on the dorsum of the body of the penis, where they are termed the corpora cavernosa. The bulb is continued forwards as the corpus cavernosum urethræ (corpus spongiosum), which forms the ventral part of the body of the penis.

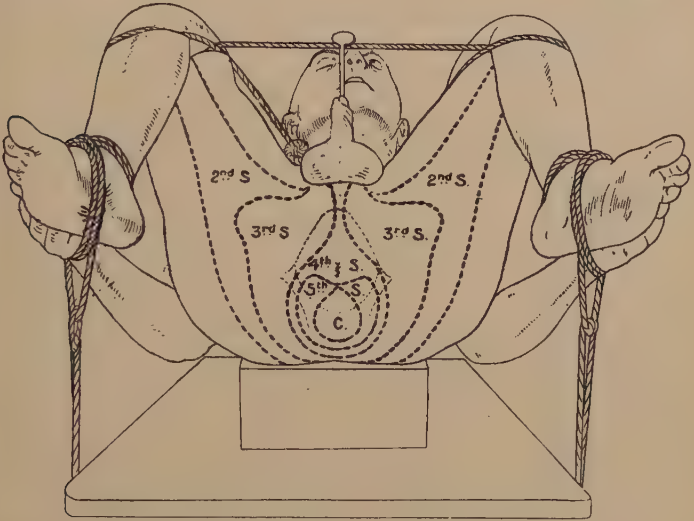

FIG. 116.—The Segmental Supply of the Skin in the Perineum.

The *superficial transverse perineal muscle* lies in the most posterior part of the superficial perineal pouch (Fig. 115). It cannot be exposed without incising the fascia of Colles, and it forms an important landmark in perineal surgery.

The **Central Point of the Perineum** (Fig. 114) is a fibro-muscular node which lies between the ano-rectal junction and the apex of the prostate. It serves as a point of origin for the sphincter ani externus and the bulbo-cavernosus, and as a point of insertion for the recto-urethral (p. 373) and superficial transverse perineal muscles and the levatores prostatæ. In the female it lies between the ano-rectal junction and the posterior vaginal wall and is termed the *perineal body*.

Superficial Perineal Nerves.—(1) The *posterior scrotal* nerves, two in number on each side, arise from the pudendal (S. 2, 3, and 4) and supply the skin over the urogenital triangle and the scrotum.

(2) The *long perineal branch* (*long pudendal*) of the posterior cutaneous nerve of the thigh (S. 1, 2, and 3) assists in the supply of the same areas.

(3) The *dorsal nerve of the penis* arises from the pudendal (S. 2, 3, and 4) and runs along the dorsum of the penis. It ends by supplying the glans.

(4) The *perforating cutaneous nerve* (S. 2 and 3) supplies the skin in the neighbourhood of the coccyx.

(5) The *perineal branch* of S. 4 supplies the skin round the anus.

(6) The *inferior hæmorrhoidal nerve* (p. 380) helps the perineal branch of S. 4 to supply the skin round the anus.

The superficial nerves of the perineum all spring from the anterior rami of the sacral nerves. Pain may be referred to this region in irritative conditions of those viscera which receive their nerve-supply from the same source, *e.g.* bladder, rectum, seminal vesicles, etc. It has already been pointed out (p. 375) that irritation of the perineal nerves may reflexly affect the viscera mentioned.

The **Urogenital Diaphragm** separates the perineum from the pelvis anteriorly. It is formed by the sphincter urethræ and the deep transverse perineal muscles, which are enclosed between two layers of fascia. The two fascial layers blend with one another, with the fascia of Colles and with the central point of the perineum, inferiorly, and they are attached on each side to the margin of the pubic arch. The superior fascia (deep layer of triangular ligament) blends, above, with the prostatic sheath, while the inferior fascia (superficial layer of triangular ligament) forms the postero-superior wall of the superficial perineal pouch. The space between the two layers is completely closed and is termed the *deep perineal pouch*. It contains (1) the membranous portion of the urethra and its sphincter muscle, (2) the deep transverse perineal muscle and the bulbo-urethral glands (of Cowper), (3) the artery to the bulb, and (4) the internal pudendal vessels and the dorsal nerve of the penis.

Rupture of the membranous portion of the urethra leads to extravasation of urine into the deep perineal pouch, and the extravasated urine can only find an exit from this space by bursting through either the anterior or the posterior wall of the pouch. In the first case, the urine then passes into the superficial perineal pouch, and its subsequent course is described on p. 378. In the second case it enters the interval which lies immediately below the pubo-prostatic ligaments (Fig. 115), and bursts through between them, gaining the retro-pubic space. It then ascends the anterior abdominal wall between the transversalis fascia and the parietal peritoneum. Extravasated urine will also be found in this situation after rupture of the prostatic urethra, and after extra-peritoneal rupture of the bladder.

The **Internal Pudendal Artery,** on leaving Alcock's canal, pierces the base of the urogenital diaphragm and runs forwards in the lateral part of the deep perineal pouch. It pierces the inferior fascia of the diaphragm under cover of the crus penis and ends by dividing into the *deep artery of the penis* (*artery to the corpus cavernosum*) and the *dorsal artery of the penis*. Before it enters the pouch, it gives off superficial branches, which ramify in the superficial pouch and supply the muscles and skin.

In the deep perineal pouch, the internal pudendal gives off the important *artery to the bulb,* which runs medially and pierces the inferior fascia of the urogenital diaphragm near the middle line in order to reach the bulb. It usually lies three-quarters of an inch from the base of the diaphragm. In the old operation of *lateral lithotomy,* the point of the knife was entered 1½ inches in front of the anus and just to the left of the middle line, and was carried backwards and laterally through the left ischio-rectal fossa towards a point midway between the anus and the tuber ischii. In this way the whole of the incision lay behind the artery to the bulb. The posterior fibres of the bulbo-cavernosus and the superficial transverse perineal muscle and artery were divided in the anterior part of the wound, and the urethra was reached by incising the inferior fascia of the urogenital diaphragm and the sphincter urethræ. The point of the knife was then carried along the grooved staff into the bladder, cutting through the left lobe of the prostate and its sheath.

Perineal Prostatectomy.—In this operation the prostate is approached from below and behind.

A curved incision, convex forwards, is made a short distance in front of the anus and is deepened until the central point of the perineum is reached. Blunt dissection with the fingers defines the lateral limits of that structure and it is then divided in the line of the skin incision. This necessarily involves the division of the recto-urethrales (p. 373) and the anterior fibres of the external sphincter. The fingers may now be inserted into the cellular interval between the prostatic sheath and the rectum and the two viscera can readily be separated. The urethra is then incised at the apex of the prostate, by cutting on a staff with a median groove. The incision should not be more than a third of an inch long and should not injure the sphincter urethræ. The staff may then be withdrawn and Young's prostatic tractor is passed into the bladder through the incision in the urethra. By its means, the prostate is drawn downwards and backwards till it appears in the wound. Its sheath is then incised on each side, and the two halves of the prostate are removed separately.

This operation was introduced by Young, of Baltimore, with a view to preserving the ejaculatory ducts and the prostatic urethra. Further, the mucous coat of the bladder is not interfered with, and perineal drainage is obtained through the urethral wound.

Development of the Genito-Urinary Organs.—The part of the gut which lies caudal to the origin of the allantois (Fig. 89) is known as the cloaca, and it becomes subdivided by a frontal (coronal) mesodermal septum into ventral and dorsal portions. The ventral portion is differentiated into a dilated upper part which forms the bladder, and a narrower lower part which is termed the *urogenital sinus*, and the latter receives the openings of the Wolffian ducts. The dorsal portion of the cloaca forms the rectum, and, probably, other parts of the large intestine.

Prior to this subdivision, the ectoderm and entoderm in the ventral wall of the cloaca are in direct apposition—no mesoderm intervening—over an area which is termed the *cloacal membrane*. In the adult, this corresponds roughly to the area between the symphysis pubis and the tip of the coccyx. The septum which subdivides the cloaca reaches the cloacal membrane and divides it into two parts, which are known as the *urogenital* and *anal membranes*, respectively. About the eighth week of fœtal life the urogenital membrane breaks down, and the bladder thus acquires an opening on the surface of the perineum.

At the cephalad end of the cloacal membrane, the ectoderm becomes heaped up to form an elevation, which, in the male, becomes the *phallus*. Before the urogenital membrane breaks down, the urogenital sinus extends forwards, so that after the rupture it opens not only on the perineum but also on the caudal aspect of the phallus. As the latter rapidly increases in the male to form the penis, the opening extends forwards and, *pari passu*, becomes closed posteriorly, so that the urethra, which is thus derived from entoderm, ultimately opens on the ventral surface of the penis at the base of the glans. At a later stage, the urethra extends into the glans and the orifice migrates forwards to the apex. It is still doubtful whether the terminal part of the urethra is ectodermal or entodermal in origin.

In the female, the genital eminence forms the clitoris, which is homologous with the penis.

Congenital Anomalies.—(*a*) *Hypospadias*. The simplest variety of hypospadias is due to persistence of the orifice at the base of the glans; the highest degree is found where the phallus remains diminutive, and the membranous urethra opens on the surface of the perineum. Intermediate degrees of this anomaly may occur.

(*b*) In *Epispadias,* the urethra opens on the dorsal surface of the penis near its attachment to the anterior abdominal wall. This abnormality is due to rupture of the urogenital membrane at a point cephalad to the genital eminence instead of caudal to it.

(*c*) In some cases, the urogenital membrane is more extensive than normal, and rupture cephalad to the genital eminence not only gives rise to epispadias but the cleft is continued forwards and *complete extroversion of the bladder* is produced. In this condition, the lower part of the anterior abdominal wall is deficient and the two pubic bones fail to meet one another in the middle line, so that the symphysis is absent. The posterior wall of the bladder is exposed on the surface below the umbilicus and forms a somewhat triangular red area, on which the ureters and genital ducts open. The margins of the mucous membrane are continuous with the skin of the abdominal wall. Complete extroversion of the bladder is always accompanied by epispadias.

The Scrotum.—Two lateral swellings, which are termed the *labio-scrotal folds,* lie one on each side of the genital eminence. As they grow tailwards, they pass lateral to the perineal orifice of the urogenital sinus, and they blend with one another in front of the anus in the male to constitute the scrotum. *In the female,* the labio-scrotal folds do not fuse with one another but persist in their entirety and constitute the labia majora.

The **Urachus** is a fibrous cord which extends in the adult from the apex of the bladder to the umbilicus. It lies between the fascia transversalis and the parietal peritoneum and represents the embryonic connection between the cloaca and the allantois, after the formation of the umbilical cord (p. 291). This connection normally disappears quite early, but it may persist and give rise to *cysts* or *umbilical urinary fistulæ.*

Congenital Anomalies of the Rectum and Anal Canal.—The *anal membrane* (p. 384) lies at the bottom of a surface depression, which is termed the *proctodæum.* During the third month, the anal membrane breaks down and the alimentary canal opens on the perineum. The upper half of the anal canal is entodermal in origin, but its lower half is derived from the ectoderm lining the proctodæum.

Should the anal membrane fail to break down, the condition of *imperforate anus* results. In some cases, the condition is very simple, and a small incision through the anal depression at once opens the lower end of the rectum. In other cases, however, the rectum ends blindly two or three inches or more from the surface. It is probable that, in these cases, the mesoderm, which separates the urogenital and anal membranes, has invaded the latter and, by rapid proliferation, has widely separated its two layers from one another.

Connections of the rectum with the bladder or prostatic urethra are due to failure of the mesodermic septum to effect a complete subdivision of the cloaca into ventral, urinary, and dorsal, intestinal segments.

In **Excision of the Rectum**, the method adopted depends entirely on the extent of the disease. The operation which is described here is chosen when a permanent colostomy has been previously established; and it is carried out with the patient in the exaggerated lithotomy position. In order to prevent any leakage during the subsequent manipulations, the anus is stitched up and an incision is made through the skin and fascia around it. This is continued backwards in the median plane up over the coccyx and lower part of the sacrum, if considered necessary. The posterior part of the incision is deepened and the median raphe of the levatores ani is split as far back as the coccyx. In the removal of the coccyx, which constitutes the next step, the glutæus maximus must be separated from its dorsal surface and the attachments of the coccygeus and the sacro-spinous and sacro-tuberous ligaments (small and great sacro-sciatic ligaments) to its sides require to be cut through. The bone may then be disarticulated from the sacrum or, if necessary, the lower part of the sacrum may be removed, but the bone must be divided below the third pair of sacral foramina, *otherwise incontinence of urine and fæces will result.*

The middle sacral artery (p. 374) is ligatured, and then, by dissection with the fingers, the levator ani is separated from the rectum on each side and the visceral layer of the pelvic fascia is torn through as it passes from the upper surface of the muscle on to the gut. In the region of the rectal ampulla, the fingers may be gradually insinuated round the bowel, passing between it and the base of the bladder and prostate. One blade of a pair of scissors is next inserted above the levator ani at the point where the median incision meets the incision round the anus, and, with the other blade in the circular incision, the wound is deepened around the anal canal. In this process the levatores ani are divided until their anterior free borders are reached on the antero-lateral aspect of the rectum. Anteriorly, the attachments of the recto-urethrales and the external sphincter to the central point of the perineum require to be cut through, and the former must be divided as close to the rectum as possible, in order to avoid injuring the membranous part of the urethra.

As a result of this step, the anal canal and the lower two inches of the rectum can be dragged downwards and a further inch can be freed, with the fingers and with scissors, from its anterior peritoneal covering.

Some difficulty will be experienced in dragging down more of the rectum, as it is anchored in place by the cellular tissue in which the middle hæmorrhoidal vessels are embedded. These "lateral ligaments" having been clamped and divided, the bowel is only held by its peritoneal covering. The peritoneum is incised transversely, close to the rectum, along the recto-vesical line of reflexion. As the bowel is gradually pulled down, the peritoneum is incised along each side and the branches of the superior hæmorrhoidal artery are secured as they are met with.

After the bowel has been mobilised for some distance above the diseased area, its peritoneal surface is stitched to the cut recto-vesical peritoneum. Just below the sutured area, the bowel is ligated and cut through, and it can then be lifted away. The proximal cut end may be surrounded with a purse-string suture and invaginated, the usual procedure in closure of the large intestine.

This operation produces less shock than some of the more extensive operations which provide the patient with a new rectum and anal canal. In such operations the pelvic colon is mobilised (p. 347) so as to permit of its being stitched to the anus, and, at the same time, the external sphincter is preserved.

The **Male Urethra** is about nine inches long from its internal orifice at the neck of the bladder to its external orifice on the glans penis. It may be conveniently divided into a *posterior, fixed portion,* consisting of the prostatic and membranous parts and the part within the bulb, and an *anterior, movable portion,* situated in the corpus cavernosum urethræ (corpus spongiosum).

In the flaccid condition of the penis, the urethra follows an ∽-shaped bend, but when the penis is drawn upwards towards the abdomen, its course becomes *J*-shaped. By this alteration, the surgeon is enabled to pass a rigid instrument with a single curve along the urethra into the bladder.

The **Prostatic Part of the Urethra** is about 1½ inches in length and is embedded in the prostate, somewhat nearer to the anterior than to the posterior surface. It is the widest and also the most dilatable part of the urethra. About half an inch wide at its mid-point, it narrows slightly at each end, but it may be dilated so as to permit the passage of the finger into the bladder. On account of this distensibility, the removal of stones from the bladder was at one time carried out through the prostatic urethra.

A longitudinal ridge, termed the *urethral crest,* occupies the floor of the prostatic urethra in nearly its whole extent. Longitudinal grooves lie one on each side of the crest; they are termed the *prostatic sinuses* and receive the prostatic ducts. It is in these ducts that chronic gonorrhœal inflammation may linger in posterior urethritis. Near the lower end of the crest, a small median opening leads into a blind diverticulum, which passes upwards and backwards below the middle lobe of the prostate. This is termed the *prostatic utricle* (*sinus pocularis*), and near its orifice, which is sometimes large enough to entangle the point of a fine instrument, the prostatic urethra receives the openings of the *ejaculatory ducts*. Gonorrhœal infection of the posterior urethra may spread into the ejaculatory ducts and involve the seminal vesicles, or it may spread along the ductus (vas) deferens and give rise to epididymitis.

The **Membranous Part of the Urethra** is narrower than any other part of the urethra except the external orifice. It is only three-quarters of an inch long, and it lies between the two fascial layers of the urogenital diaphragm, surrounded by its sphincter muscle (p. 382).

The *bulbo-urethral glands* (*of Cowper*) lie infero-lateral to the membranous urethra, and their ducts pierce the inferior fascia of the diaphragm (p. 382) to open into the cavernous urethra. These glands are sometimes involved in gonorrhœal inflammation of the anterior urethra, and they may give rise to abscesses, which can be recognised on rectal examination. The pus should be evacuated through the perineum.

The **Cavernous (Spongy) Part of the Urethra** is about six or seven inches long and is enclosed in the bulb, the corpus cavernosum (spongiosum) urethræ and the glans penis. The external orifice on the glans is the narrowest part of the canal, and it may require to be incised to permit the passage of bougies, which will then readily pass along the remainder of the urethra. Enlargement of the external urethral orifice should be carried out by cutting from within outwards towards the frænulum.

Immediately within the external orifice, the urethra widens out to form the *fossa navicularis*, which involves the roof rather than the floor of the canal. Near the posterior end of the fossa a fold of mucous membrane projects downwards from the roof and may temporarily hinder the passage of an instrument, but, by directing the point of the instrument towards the floor of the urethra, this slight obstruction is easily avoided.

Behind the fossa navicularis, the urethra becomes narrower, but it again enlarges when it reaches the bulb. This is the most dependent part of the fixed urethra, and, on this account, is the commonest site of chronic gonorrhœal inflammation, and, consequently, of organic stricture.

Stricture may occur at any point in the cavernous urethra. When more than one is present, the first should be dilated to full size before the next is dealt with. If this is not done, it may be impossible to determine whether a bougie is obstructed by a deep stricture or whether its shoulders are caught in the one first encountered.

In negotiating a difficult stricture in the bulb, great care and gentleness must be exercised lest a false passage be made. The surgeon stands on the left side of the patient and manipulates the handle of the instrument with his right hand. This leaves his left hand free, and the left forefinger, if inserted into the rectum, may be of great assistance in guiding the point of the instrument, thus preventing the formation of a false passage.

The passage of a rigid instrument, No. 8 or 9, along a healthy urethra into the bladder presents no difficulty, if its point is kept in contact with the roof of the urethra after the fossa navicularis has been traversed. When a small instrument is used, some difficulty may be experienced in passing from the bulb into the membranous urethra as, unless the point is kept along the roof of the canal, it impinges against the urogenital diaphragm just below the urethral opening. In these cases, the instrument should be withdrawn for a short distance and then the handle should be depressed so that the point may rise towards the orifice in the diaphragm.

The **Body of the Penis** consists of the two *corpora cavernosa*, which lie side by side on the dorsum, and the *corpus cavernosum urethræ* (*c. spongiosum*), which lies in the groove separating the two corpora cavernosa ventrally. At its termination, the corpus cavernosum urethræ expands into a conical enlargement, termed the *glans penis*, which projects dorsally and laterally, so as to cover the extremities of the corpora cavernosa.

The component parts of the penis contain numerous venous spaces, in which the blood may be retarded by the contraction of the ischio-cavernosi and the bulbo-cavernosus (p. 381), leading to enlargement of the organ. In conditions of gonorrhœal inflammation, the spaces in the corpus cavernosum urethræ, being already filled with serous exudate, fail to distend when the corpora cavernosa are undergoing distension. As a result, the penile erection is not straight but is curved, owing to the inelastic condition of the corpus cavernosum urethræ. This constitutes the condition which is known as chordee.

The skin of the penis is very thin, and is freely movable over the body of the organ. At the extremity of the penis it is folded back to form a hoodlike covering for the glans. This is termed the *prepuce*; its deep surface is lined by modified skin, which is reflected on to the glans (1) at its base, the corona glandis, and (2) on its ventral aspect, where it forms the frenulum. The modified skin covering the glans is firmly adherent, and contains sebaceous glands, which secrete the smegma. The latter collects in the region of the corona glandis, and may sometimes form concretions.

In the condition of **Phimosis** there is a long narrow prepuce, which cannot be drawn back off the glans. Adhesions between the deep surface of the prepuce and the skin surface of the glans may give rise, reflexly, to urinary disturbances. The whole condition may be relieved by circumcision. In this operation the prepuce is drawn forwards over the apex of the glans and removed. When adhesions are present the prepuce itself cannot be drawn forwards, and the skin which is drawn forwards is derived from the body of the penis. If this portion is cut away, the cut proximal end at once retracts, and the penis may be almost completely denuded, while the prepuce is left intact, *i.e.* a circular strip of skin is removed from the body of the penis.

In the normal case, when the prepuce is cut away, the external covering of skin retracts, but the deep layer remains in contact with the glans. This layer may be slit along the dorsal surface with scissors, but care must be taken not to insert the point of the lower blade into the external urethral orifice. Thereafter, each portion of the deep layer of the prepuce may be stripped from the glans with the fingers, and a layer of smegma is usually disclosed around the corona.

On the dorsal surface tributaries of the dorsal vein and branches of the dorsal arteries of the penis will require to be tied. In addition, if the frenulum is divided, the little artery which runs in it must be secured; it is a branch of one of the arteries to the bulb. The cut edge of the skin is then stitched to the deep layer of the prepuce.

The condition of **Paraphimosis** results when a tight prepuce is drawn backwards off the glans and allowed to remain as a constricting band above the corona. The glans becomes engorged and œdematous, and actual gangrene may ensue, unless the prepuce is replaced. This may be carried out by exercising steady pressure on the glans with the thumbs while traction on the prepuce is maintained by the encircling fingers.

The **Superficial Dorsal Vein of the Penis** arises on the dorsum just behind the glans by the union of small tributaries from the glans and prepuce. It runs backwards in the middle line immediately under the skin of the dorsum, and ends by dividing into right and left branches, which join the superficial external pudendal veins.

The **Deep Dorsal Vein of the Penis** lies on a deeper plane. It passes into the pelvis between the symphysis pubis and the upper edge of the urogenital diaphragm (Fig. 115), and finally it divides into right and left branches, which join the pudendal (prostatic) plexus of veins.

Each **Dorsal Artery of the Penis** arises from the internal pudendal (p. 383), and runs forwards on the dorsal surface of the corpus cavernosum; which it supplies.

The **Dorsal Nerve of the Penis** (S. 2, 3, 4) is derived from the pudendal (p. 379). It lies lateral to the dorsal artery and supplies branches to the skin of the penis, prepuce, and glans.

The superficial and the deep *lymph vessels* of the penis end, respectively, in the superficial and the deep subinguinal lymph glands (p. 405).

THE FEMALE PELVIS.

The differences between the male and female generative organs necessitate a somewhat different arrangement of the **Pelvic Peritoneum** in the female.

On leaving the anterior surface of the rectum, the peritoneum passes forwards, forming the floor of the recto-uterine fossa, and reaches the posterior aspect of the vagina, which it clothes in its upper fifth. From the posterior surface of the vagina the peritoneum passes upwards on the posterior surface of the uterus to the fundus. It then descends over the anterior surface of the uterus, but at about one inch above the vagina it passes forwards on to the superior surface of the bladder, forming the floor of the utero-vesical fossa (Fig. 117).

The **Broad Ligament of the Uterus** is a somewhat triangular sheet of peritoneum which extends laterally from the lateral border of the uterus to the pelvic wall. It consists of two layers which become continuous with one another at the upper free border of the ligament, where they enclose the uterine (Fallopian) tube. Infero-laterally the two layers separate

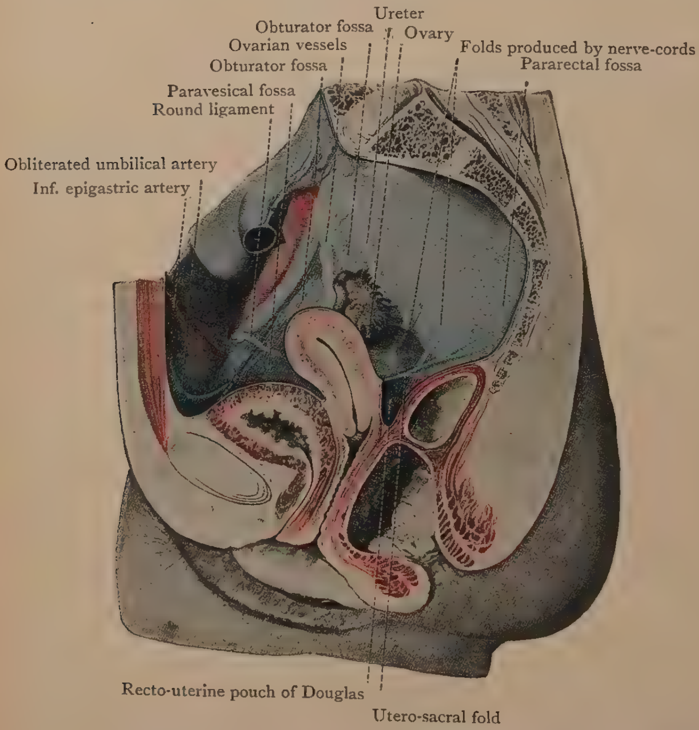
Ureter
Obturator fossa
Ovary
Ovarian vessels
Folds produced by nerve-cords
Obturator fossa
Pararectal fossa
Paravesical fossa
Round ligament
Obliterated umbilical artery
Inf. epigastric artery
Recto-uterine pouch of Douglas
Utero-sacral fold

FIG. 117.—Median Section through the Female Pelvis to show the disposition of the Peritoneum. (Dixon and Birmingham.)

to cover the floor and side-walls of the pelvis. The plane of the broad ligament depends partly on the position of the uterus. Normally its anterior surface is directed downwards and slightly forwards.

Certain parts of the broad ligament receive special names. (1) The *mesosalpinx* is the part which lies immediately below the uterine tube. (2) The *mesovarium* is the fold which passes from the posterior layer of the broad ligament to enclose the ovary. It contains the ovarian vessels, nerves, and lymphatics. (3) The *suspensory ligament of the ovary* is that part of the broad ligament which extends between the upper pole of the ovary and the pelvic wall. Its lateral attachment is placed a little below and behind the abdominal inguinal ring (p. 268). The ovarian vessels, etc., traverse the suspensory ligament on their way to the mesovarium.

The **Vagina**, which is about three inches long, is directed upwards and backwards and lies in the interval between the urethra and bladder, in front, and the anal canal and rectum, behind. Its upper half lies above the level of the muscular floor of the pelvis, and is surrounded by the visceral pelvic fascia. Its lower half is embraced by the levatores ani, and at a lower level, by the bulbs of the vestibule (p. 401), and the bulbocavernosus (sphincter vaginæ) muscle.

Superiorly, the vagina is attached around the cervix uteri, which projects obliquely downwards and backwards into the canal. Around the cervix there is a shallow groove, termed the *fornix*, which is deepest posteriorly.

Anteriorly, the lower part of the vagina is related to the urethra. This area may undergo sloughing from continual pressure during parturition, and a urethro-vaginal fistula may result. Above this level, the vagina is related to the posterior surface of the bladder, from which it is only separated by some loose cellular tissue, as it lies entirely below the peritoneum of the utero-vesical fossa. This arrangement is of great importance to the surgeon, as it permits the bladder to be easily separated from the cervix and vagina. It is through this area, too, that malignant diseases of the cervix may spread to the bladder.

Posteriorly, the vagina is related to the anal canal and rectum. In its lower part it is separated from the anal canal by a fibromuscular mass which is termed the perineal body, and in its upper fifth or more it is separated from the rectum by the lowest part of the recto-uterine fossa and the viscera which it contains.

During parturition the posterior commissure (p. 401) may give way, and the laceration may involve the skin and superficial tissues of the perineum as far back as the anus. The posterior wall of the vagina may also be involved, and occasionally the perineal body, into which the anterior fibres of the levator ani are inserted, and the sphincter muscles of the anal canal are affected. Incontinence of fæces only occurs when the internal sphincter is torn through.

Following severe *lacerations of the perineum* which involve the perineal body, the posterior vaginal wall may become prolapsed through the vulva. This condition is usually accompanied by a dilatation of the ampulla of the rectum, which pouches forwards into the relaxed posterior vaginal wall, constituting the condition known as a *rectocele*. A strain is thus placed on the anterior wall of the vagina, and it in turn becomes prolapsed, dragging the bladder with it to form a *cystocele*. Lastly, the uterus itself descends, and a complete prolapse is the final stage.

In the operation of *colporrhaphy*, which is undertaken as a remedial measure, oval areas of mucous membrane are removed in the long axis of the anterior and posterior vaginal walls, and the cut edges are then stitched together, thus narrowing the vagina. In removing the mucous membrane of the anterior vaginal wall and in stitching the cut edges together subsequently, great care must be taken to avoid injuring the bladder and urethra. When the perineal body has been torn through the two parts must be sutured in order to restore the pelvic floor.

The **Uterus** is about three inches long and two inches broad, and in shape resembles a pear, flattened antero-posteriorly. At the upper ends of its lateral borders it receives the uterine tubes, and the part of the organ which lies above this level is termed the *fundus*. This part of the uterus is normally directed forwards, and is completely covered by the peritoneum, which is firmly adherent to it.

The *body of the uterus* lies below the fundus, and is separated from the cervix by a slight constriction, termed the isthmus. It is completely covered by peritoneum, which separates it, anteriorly, from the superior surface of the bladder, and posteriorly, from the recto-uterine fossa. The body of the uterus is the common site for fibroids, which may grow in the subserous, muscular, or submucous coats.

The **Cervix Uteri** consists of a supra-vaginal and a vaginal portion. The supra-vaginal portion is covered by peritoneum on its posterior surface only, and this covering is very loosely attached to the subjacent muscular coat. Anteriorly, the supra-vaginal portion of the cervix is related to the bladder, from which it is separated by some cellular tissue (p. 400).

The vaginal portion of the cervix projects downwards and backwards into the antero-superior part of the vagina, and receives a covering of squamous epithelium similar to that which lines the vagina.

The cervix is traversed by the cervical canal, which communicates with the cavity of the uterus, above, through the *internal orifice*, and with the vagina, below, through the *external orifice*. In nulliparæ the external orifice of the uterus is a circular depression, and, owing to the line of axis of the cervix, is directed against the posterior vaginal wall. In multiparæ the orifice becomes an irregularly transverse slit, with somewhat everted anterior and posterior lips. The cervical canal readily admits a sound 4 mm. in diameter. Should it fail to do so, the condition of stenosis is present. *Stenosis* of the cervix obstructs the menstrual flow, and gives rise to dysmenorrhœa, which is most marked at the commencement of the period.

Position of the Uterus.—The long axis of the uterus is normally directed downwards and backwards, and this arrangement is described as *anteversion* of the organ. But in addition to being anteverted, the normal uterus is bent forwards on itself at the junction of the body with the cervix, and this condition is termed *anteflexion*. The position of the uterus varies somewhat with the condition of the bladder, but the organ is prevented from becoming retroflexed and retroverted by two ligaments on each side.

The *round ligament* is a fibro-muscular band, which is attached to the uterus just below the uterine tube. It passes laterally in the broad ligament, and projects slightly from its anterior layer. On leaving the broad ligament, the round ligament of the uterus enters the abdominal inguinal ring, traverses the inguinal canal, and emerges from the subcutaneous inguinal ring to be attached to the skin and subcutaneous tissue of the labium majus (p. 401). Its relations at the abdominal inguinal ring and in the canal are precisely the same as those already described for the spermatic cord (p. 257).

The operation of shortening the round ligaments is sometimes carried out in cases of retroflexion, but abdominal hysteropexy, which consists in suturing the fundus to the anterior abdominal wall, is more frequently performed.

The *utero-sacral ligaments* are fibro-muscular bands, which extend from the posterior surface of the uterus just above the cervix to the posterior wall of the pelvis lateral to the rectum. They are extra-peritoneal, but produce peritoneal ridges, which are known as the utero-sacral folds. These ligaments may become shortened, following inflammatory conditions of the perimetrium, and drag the lower part of the uterus backwards, giving rise to acute anteflexion.

In a *retroflexed uterus*, the cervix assumes a more vertical position, and the external orifice of the uterus may be directed straight down the vagina. In this position, the flexion at the isthmus may be sufficiently pronounced to cause difficulty in the evacuation of the menstrual discharge.

The pregnant uterus ascends from the pelvis into the abdomen as it enlarges in size, but the *retroverted gravid uterus* is prevented from doing so by the sacral promontory. The enlargement of the viscus, therefore, causes increased intra-pelvic pressure, and the urethra is pressed against the symphysis pubis, causing first retention of urine, and later, the overflow from a distended bladder. If the position of the uterus is corrected, the pregnancy will follow a normal course.

The **Uterine (Fallopian) Tube** is attached to the uppermost part of the lateral border of the uterus, and extends laterally in the free upper margin of the broad ligament towards the pelvic wall, where it is closely related to the medial surface of the ovary (Fig. 117).

The part of the tube which is embedded in the uterine wall is known as the *pars uterina*. Lateral to it, the tube possesses for a short distance well-marked longitudinal and circular muscular coats. In this portion, which is termed the *isthmus*, the lumen is very small. Lateral to the isthmus, the muscular coat is not so strongly developed, but the mucous coat is very much thicker. This part of the tube is known as the *ampulla*, and its extremity widens out into the *infundibulum*, which is a funnel-like depression, the walls of which are formed by numerous narrow processes, called the *fimbriæ*. These processes project from the broad ligament, and are completely covered by peritoneum. One of them, *the fimbria ovarica*, is constantly attached to the upper pole of the ovary. At the bottom of the infundibulum, the uterine tube communicates with the peritoneal cavity through the *ostium abdominale*, and at this point the peritoneal endothelium merges into the ciliated epithelium which lines the tube.

As the ova are discharged from the ovary, they pass at once into the peritoneal cavity, and only those that gain entrance to the ostium abdominale have any chance of becoming fertilised. Occasionally, a fertilised ovum fails to be carried along the tube into the uterus and continues to develop in the tube itself. This condition is known as *tubal gestation,* and as the ovum enlarges, gives rise to abdominal symptoms, which are frequently misinterpreted. Tubal abortion may occur through the ostium abdominale, and in this case the hæmorrhage varies in severity. Occasionally, it is excessive and calls for surgical interference. Failing a tubal abortion, the ovum increases in size until the uterine tube ruptures, when the extent of the subsequent hæmorrhage will depend on the site of the rupture. If the tube gives way in the lower two-fifths of its circumference, the hæmorrhage occurs between the two layers of the broad ligament, and is consequently limited in amount. On the other hand, if the tube ruptures in the upper three-fifths of its circumference, the hæmorrhage occurs into the peritoneal cavity, and unless it is restricted by the partial obliteration of the cavity owing to adhesions, it is so severe that immediate laparotomy is imperative.

The **Ovary** is an almond-shaped body about 1 to 1½ inches long by half an inch wide. It projects from the posterior layer of the broad ligament, which it draws out to form the mesovarium. It is covered by peritoneum which is somewhat altered in character, and which is termed "germinal epithelium."

In nulliparæ, the ovary lies on the side wall of the pelvis in a small peritoneal recess, termed the *fossa ovarica,* which is limited above by the external iliac vessels and behind by the ureter. Its medial surface is related to the uterine tube, and its anterior border is connected to the posterior layer of the broad ligament by the mesovarium. From its upper pole, which gives attachment to the fimbria ovarica, the peritoneum passes to the side wall of the pelvis as the suspensory ligament. The lower pole of the ovary is attached to the uterus by a fibro-muscular band, known as the ovarian ligament.

The **Ovarian Artery** arises from the aorta opposite the second lumbar vertebra, and passes downwards and laterally on the psoas major to reach the brim of the pelvis, where it enters the suspensory ligament. It gives off a few twigs to the uterine tube, and one or two branches which run medially in the mesosalpinx to anastomose with the uterine artery, but the main stem of the vessel enters the mesovarium to supply the ovary. In the latter part of its course the artery is very tortuous, and is surrounded by the pampiniform plexus of veins, which unite to form the ovarian vein in the suspensory ligament.

Owing to the free anastomosis of the ovarian and uterine arteries, the peritoneum on each side of the ovary must be seized with forceps when the organ is being removed. Ligature of the vessels should be carried out by transfixing the broad ligament, otherwise the sutures may slip and give rise to troublesome hæmorrhage owing to the retraction of the cut vessels.

Dermoid or other cysts arising in connection with the ovary may or may not possess a pedicle of peritoneum. When they do, the pedicle consists of the mesovarium and its contained vessels. Twisting of the pedicle produces kinking of the artery and cuts off the blood-supply of the tumour. In other cases, the cyst may grow in between the two layers of the broad ligament, and separate them as it enlarges. The peritoneum may be stripped off the pelvic wall and the iliac colon, and the commencement of the pelvic colon may be denuded. When the tumour is removed, great care must be exercised lest these parts of the bowel be injured, as they are in intimate relationship with it.

A large ovarian cyst with a long pedicle may be mistaken for a movable kidney, as manipulations may be successful in placing it in the loin (p. 355), but as soon as the manual pressure is taken away, it tends to sink down towards the pelvis.

The **Ep-oöphoron** (**Parovarium**) lies between the two layers of the broad ligament below the ampulla of the uterine tube. Cysts of the ep-oöphoron rarely possess a pedicle, and, as they enlarge, they separate the two layers of the broad ligament. The ep-oöphoron represents a persistent part of the Wolffian body (p. 271) and consists of a number of small vertical tubules, which join a horizontal duct. This duct usually ends blindly, but it varies in length and may be continued downwards to the vagina, where it sometimes opens. It is then known as the *duct of Gærtner*, and it corresponds to the ductus deferens in the male.

Cysts may arise in the lower part of the duct and project into the vagina.

Development of the Uterus, etc.—Shortly after the appearance of the Wolffian ducts (p. 271), two other longitudinal ducts appear. These are known as the *Mullerian ducts*. At their cephalad extremities they open into the body-cavity, and their caudal extremities, though ending blindly at first, subsequently open into the lowest part of the cloaca. The caudal two-thirds of the Mullerian ducts fuse to form the uterus and vagina, but their cephalad thirds remain separate and form the uterine (Fallopian) tubes. The latter retain their primitive connection with the body-cavity as the ostium abdominale.

The two Mullerian ducts, although lying side by side, may fail to fuse. In this case the vagina is divided into right and left halves by a median septum and the uterus is bicornuate. The condition of *bicornuate uterus* with a normal vagina is not uncommon.

At first, the Mullerian duct is represented by a solid column of cells, which later becomes canaliculised. If this process is not carried out completely, the condition of *atresia vaginæ* is brought about.

A few of the tubules of the Wolffian body persist in the female as the ep-oöphoron (parovarium), and they retain their connection with the Wolffian duct, which is known, in the adult, as the duct of Gærtner.

Lymph Vessels of the Female Generative Organs. — The lymph vessels from the body and fundus of the uterus run laterally in the broad ligament. The majority of them, accompanied by the lymph vessels from the ovary and the uterine tube, ascend from the pelvis and join the lumbar lymph glands. Of the remainder some pass to the external iliac group and others associate themselves with the round ligament, to terminate in the medial group of the superficial subinguinal lymph glands.

The lymph vessels from the cervix uteri and the upper part of the vagina end in the hypogastric lymph glands, but those from the posterior aspect establish connections with the ano-rectal lymph glands (p. 376), on the walls of the rectal ampulla.

The lymph vessels from the lower part of the vagina join the medial group of the superficial subinguinal lymph glands (p. 405).

The **Uterine Artery**, a branch of the hypogastric, curves forwards and medially on the pelvic floor till it reaches the base of the broad ligament. It then runs medially between the two peritoneal layers to the lateral border of the uterus. At a distance of three-quarters of an inch from the uterus the uterine artery crosses above and anterior to the ureter, and, in tying the vessel, great care must be exercised not to include the ureter within the ligature. In order to avoid this danger, the artery is usually tied close to the uterus, as it lies above the lateral fornix of the vagina.

The uterine artery, after giving off a branch which descends to supply the cervix and vagina, ascends along the lateral border of the uterus, supplying it with numerous branches. Finally it ends by supplying the isthmus of the uterine tube and by anastomosing with branches of the ovarian artery.

Hysterectomy.—The operation of removal of the uterus has been much simplified by the adoption of the Trendelenberg position and the abdominal route. Access is obtained by means of a median infra-umbilical incision (Fig. 76) through the abdominal wall.

The suspensory ligaments of the ovary and the round ligaments are seized in forceps, to secure the contained arteries, and are then divided. The ovary and tube are lifted up on each side, and, lateral to them, the broad ligaments are divided medially and downwards towards the uterus. Before the uterus is reached, artery forceps are passed downwards and medially to secure the uterine artery in the interval between the point where it crosses the ureter and the point where it gives off its descending cervical branch. The peritoneal covering of the uterus is then incised transversely in front and behind so as to join the incisions already made in the broad ligaments. The fingers are inserted into the cellular interval between the bladder and the cervix, and the two viscera are carefully separated from one another. The uterus is then dragged upwards and the supra-vaginal portion of the cervix is cut through. All the cut vessels are tied, and, in order to prevent slipping, the ligatures should be passed through the peritoneum. In the case of the uterine artery, a secure hold may be obtained by passing the ligature through the stump of the cervix. Subsequently, the cut edges of the peritoneum are sutured together across the floor of the pelvis, all the ligatures being inverted beneath the peritoneum. The last step in the operation consists in placing the pelvic colon in the empty pelvis.

Both in pregnancy and in large tumours the vascular supply of the uterus is much increased, and the slipping of a ligature gives rise to formidable hæmorrhage.

A **Vaginal Examination** is best carried out with the patient in the dorsal position, the thighs being well flexed and abducted. The labia majora should first be separated, as this act draws apart the labia minora and prevents their inversion into the vagina by the examining fingers. The middle and index fingers are then inserted, and a thorough examination of the vaginal fornices may be made.

Through the anterior fornix the base of the bladder can be felt, and, when the surgeon uses his free hand to exert pressure on the anterior abdominal wall in a downward and backward direction, the body of the uterus can also be examined, if it is in the normal position. In the lower part of the anterior vaginal wall, the urethra can be recognised as a rounded cord and may be rolled against the arcuate (subpubic) ligament.

Through the posterior fornix, the fingers can palpate the contents of the utero-rectal fossa. A prolapsed ovary is at once recognised on examination by the characteristic sensation aroused in the patient. The rectum lies in close contact with the lower part of the posterior vaginal wall, and scybalous masses can be recognised by the fact that they pit on pressure. When the rectum is empty, the sacral promontory can be reached with the tip of the forefinger. The distance between it and the pubic symphysis can be estimated; normally, it amounts to 4½ inches.

Through the lateral fornices, the conditions of the broad ligaments may be estimated, and tumours, collections of pus in the uterine tubes, or the enlargement due to extra-uterine pregnancy may be recognised.

The uterine tubes, when healthy, cannot be palpated, but in the presence of salpingitis they can readily be made out on vaginal examination. When a calculus is impacted in the lower part of the ureter, it may sometimes be located per vaginam, but the normal ureter, like the normal tube, cannot be felt through the fornix.

The Female Perineum.—The *rectal triangle* shows no differences of importance, and the description given on pp. 377, 380 holds good for this area in the female.

In the *urogenital triangle* the sexual differences require further description.

The *labia majora* are two folds of skin which surround the urogenital fissure. They commence in front at the *mons veneris*, a rounded elevation on the front of the pubes, and extend backwards, meeting to form the posterior commissure just anterior to the anus. Their inner surfaces are covered by slightly modified skin, which is kept moist by the secretion of numerous sebaceous glands.

The *labia minora* are two folds of skin which lie within the urogenital fissure, one on each side of the vaginal orifice. Anteriorly each splits into upper and lower parts. The upper parts of the two sides unite above the clitoris and form the *præputium clitoridis*. The lower parts are attached to the under surface of the clitoris and constitute the *frenulum*.

The *clitoris* is homologous with the penis and possesses a similar structure, but it is very much smaller in size and is not traversed by the urethra. Dorsally it consists of two corpora cavernosa, which are covered distally by the glans. In place of the corpus cavernosum urethræ of the male, the ventral aspect of the body of the clitoris is occupied by a venous plexus, termed the *pars intermedia*, which is continuous in front with the erectile tissue of the glans.

The *root of the clitoris* consists of two crura and the bulb of the vestibule, and it lies in the superficial perineal pouch (p. 380). The *crura*, as in the male, are attached to the borders of the pubic arch and are covered by the ischio-cavernosi muscles. The *bulb of the vestibule* consists of two elongated bodies, composed of erectile tissue, which lie one on each side of the entrance to the vagina. In front they are continuous with one another and with the pars intermedia. During the stretching of the vaginal walls in parturition or from trauma these venous plexuses may be injured and give rise to a hæmatoma. The bulb is covered by the bulbo-cavernosus (sphincter vaginæ) muscle.

Between the glans clitoridis and the orifice of the vagina there is a smooth triangular area, which is pierced by the external opening of the urethra. This area is termed the *vestibule*.

The *vaginal orifice* in the virgin is partly obscured by the hymen, which consists of two folds of mucous membrane of varying shape and size. Sometimes the hymen is imperforate, and, with the onset of puberty, the condition gives rise to trouble by obstructing the menstrual flow.

The *glandulæ vestibulares majores* (of Bartholin) correspond to the bulbo-urethral glands in the male (p. 388). They lie on the lateral vaginal wall, under cover of the bulbo-cavernosus muscle, and their ducts open in the interval between the hymen and the labia minora. These glands may become infected in gonorrhœa and give rise to abscess formation.

The **Female Urethra** is only 1½ inches long, and throughout its whole extent it is closely related to the anterior wall of the vagina. As in the male, the urethra pierces the urogenital diaphragm, but its course in the superficial perineal pouch is extremely short, as it almost at once opens on the surface of the vestibule. It follows a slightly curved course, the concavity of the curve being directed forwards, and it can readily be dilated so as to permit of direct examination of the interior of the bladder. The ureteral orifices can be inspected and direct catheterisation can be carried out.

The *vessels and nerves* of the urogenital triangle in the male have been described on p. 382, and require no further mention.

THE INFERIOR EXTREMITY.

THE FRONT OF THE THIGH.

Surface Landmarks.—The bony points of the pelvis have already been described (pp. 241 and 243).

The *sartorius muscle* is rendered prominent when the hip and knee-joints are flexed and the limb is rotated laterally. It can then be recognised as a ridge passing from the anterior superior iliac spine obliquely to the medial side of the thigh. To its lateral side, just distal to the anterior superior spine, the fingers can be inserted into a depression, which is bounded laterally by the *tensor fasciæ latæ*. This depression overlies the *straight head of the rectus femoris*—which lies on the anterior aspect of the capsule of the hip-joint—and it is rendered more distinct when the patient flexes the thigh with the knee extended.

The tendon of the *adductor longus*, which arises in the angle between the pubic crest and the symphysis, can be seen when the thigh is adducted against resistance. In obese subjects, though not always visible, the tendon can be felt and traced to the pubis. The tendon may serve as a guide to the pubic tubercle, the position of which must be determined in distinguishing a femoral from a small inguinal hernia. The neck of a femoral hernia lies below the tubercle, while that of an inguinal hernia is situated above it.

Superficial Vessels.—The *great saphenous vein* (p. 452) lies in the superficial fascia on the antero-medial side of the thigh, and, having received numerous tributaries, pierces the fascia cribrosa, which partially closes the fossa ovalis (saphenous opening), to join the femoral vein.

Its proximal part is commonly exposed by the surgeon in the removal of varicose veins, and is most easily found by making a transverse incision through the skin and fascia at the distal border of the fossa ovalis (p. 406), the patient's limb being kept slightly abducted and laterally rotated.

At the point where the great saphenous joins the femoral vein there is not uncommonly a dilatation, which gives rise to a visible swelling. This may be mistaken for a femoral hernia, as there is an impulse on coughing and the swelling disappears when the patient lies down. For the purpose of differential diagnosis, the patient is examined in the recumbent posture, and a finger is placed on the proximal part of the fossa ovalis so as to control the femoral vein and also a femoral hernia, if one is present. The patient is then allowed to resume the erect attitude. The swelling, if venous in nature, gradually reappears from below as the veins fill up.

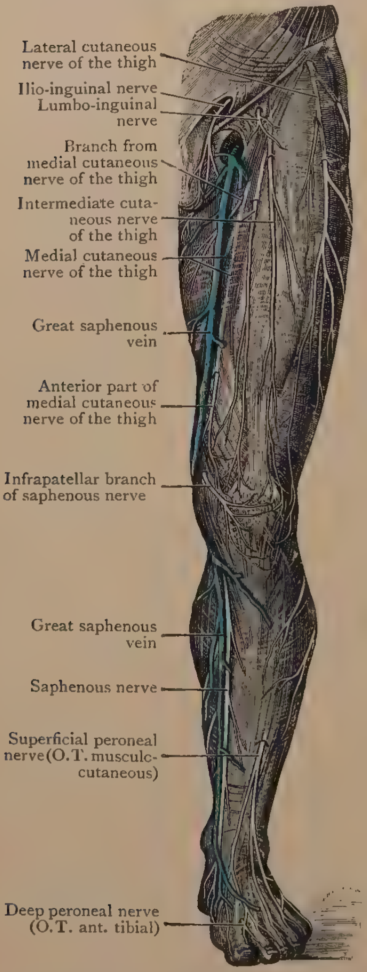
Lateral cutaneous nerve of the thigh
Ilio-inguinal nerve
Lumbo-inguinal nerve
Branch from medial cutaneous nerve of the thigh
Intermediate cutaneous nerve of the thigh
Medial cutaneous nerve of the thigh
Great saphenous vein
Anterior part of medial cutaneous nerve of the thigh
Infrapatellar branch of saphenous nerve
Great saphenous vein
Saphenous nerve
Superficial peroneal nerve (O.T. musculo-cutaneous)
Deep peroneal nerve (O.T. ant. tibial)

FIG. 118.—The Superficial Nerves and Veins on the Anterior Aspect of the Lower Limb.

The *superficial epigastric* and *external pudendal arteries* have been described on p. 257. The *superficial circumflex iliac* pierces the deep fascia lateral to the fossa ovalis and passes laterally (p. 414). All three are derived from the femoral artery.

The **Cutaneous Nerves** which supply the skin of the front of the thigh arise from the lumbar plexus.

1. The *lateral cutaneous* (L. 2, 3) enters the thigh behind the lateral extremity of the inguinal ligament, and runs behind the deep fascia for two inches before breaking up into anterior and posterior divisions, which pierce the deep fascia to supply the skin of the buttock and of the lateral aspect of the thigh as far as the knee.

2. The *lumbo-inguinal nerve* (*crural branch of the genito-crural*) (L. 1, 2) supplies an area of skin distal to the intermediate part of the inguinal ligament. It varies greatly in size, and sometimes extends to the region of the knee. In renal colic, pain is sometimes referred to the areas supplied by the lumbo- and ilio-inguinal nerves (p. 357).

3. The *intermediate cutaneous* (L. 2, 3) is a branch of the femoral (anterior crural) nerve. It supplies the skin of the front of the thigh as far as the knee (Fig. 118).

4. The *medial cutaneous* (L. 2, 3), also a branch of the femoral nerve, supplies the antero-medial aspect of the thigh. In the distal part of its course it is associated with the great saphenous vein.

5. The *ilio-inguinal* (L. 1) (p. 244) supplies a few branches to the skin of the proximal and medial part of the thigh.

6. The *obturator nerve* (L. 2, 3, 4) sends some branches through the sartorial plexus (p. 416), which are distributed posterior to the medial cutaneous nerve.

The **Superficial Subinguinal Lymph Glands**, which lie on the deep fascia distal to the inguinal ligament, are subdivided into two groups. (*a*) The *proximal group* consists of a chain of lymph glands which lie distal to and, roughly, parallel with the inguinal ligament. The lateral members of the group receive afferents from the perineum, anus, buttock, and the abdominal wall, below the umbilicus; the medial glands receive afferents from the anus, perineum, and external genitalia. (*b*) The *distal group* lies around the proximal part of the great saphenous vein and on the lateral border of the fossa ovalis (saphenous opening). This group receives all the superficial lymph vessels of the lower limb, except those from the buttock and those from the lateral side of the foot and the postero-lateral area of the leg, which enter the popliteal glands (p. 451).

Lymphangitis from septic conditions of the toes may culminate in suppurative adenitis of the distal subinguinal glands. In these cases the thigh is usually kept in the position of flexion in order to relax the overlying skin and cutaneous nerves.

The efferents from both groups of the superficial subinguinal lymph glands terminate in the **deep subinguinal glands**, which lie behind the deep fascia around the proximal parts of the femoral vessels. Abscesses in connection with this group should, therefore, be opened by Hilton's method. The efferents from the popliteal glands also end in the deep group, which sends its own efferents to the external iliac lymph glands. The most proximal member of the deep group occupies the femoral ring (p. 408).

The Deep Fascia is attached proximally to the body and tubercle of the pubis, to the inguinal ligament and the anterior superior iliac spine. Laterally, it encloses the tensor fasciæ latæ and reaches the gluteal region. On the medial side it is attached to the margins of the pubic arch as far as the ischial tuberosity, where it becomes continuous with the deep fascia of the back of the thigh. It is particularly strong over the lateral aspect of the thigh, where it is strengthened by the insertions of the tensor fasciæ latæ and glutæus maximus. This part of the fascia lata is known as the *ilio-tibial tract.*

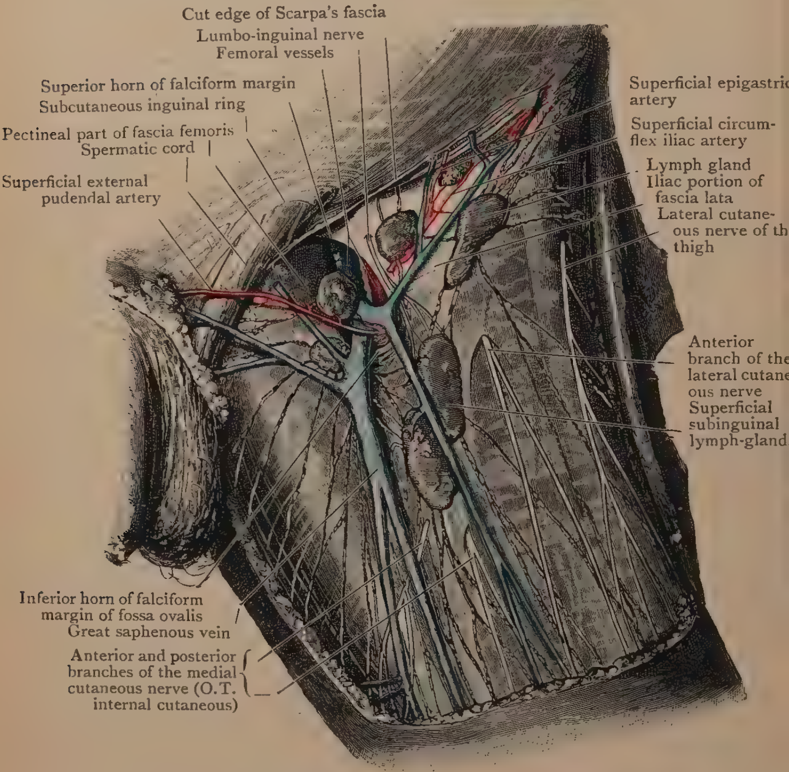
Cut edge of Scarpa's fascia
Lumbo-inguinal nerve
Femoral vessels
Superior horn of falciform margin
Subcutaneous inguinal ring
Pectineal part of fascia femoris
Spermatic cord
Superficial external pudendal artery
Superficial epigastri
artery
Superficial circumflex iliac artery
Lymph gland
Iliac portion of fascia lata
Lateral cutaneous nerve of th
thigh
Anterior
branch of the
lateral cutane
ous nerve
Superficial
subinguinal
lymph-gland
Inferior horn of falciform margin of fossa ovalis
Great saphenous vein
Anterior and posterior branches of the medial cutaneous nerve (O.T. internal cutaneous)

FIG. 119.—The Subinguinal Lymph Glands and the Fossa Ovalis (Saphenous opening).

A large gap, termed the *fossa ovalis* (*saphenous opening*), occurs in the deep fascia just distal to the medial end of the inguinal ligament. The centre of the opening lies 1½ inches distal and lateral to the pubic tubercle (Stiles). It is traversed by the great saphenous vein and is partially closed by the fascia cribrosa. The lateral border of the fossa ovalis is sharp and well defined. It is falciform in outline, and its *superior cornu*

(*Hey's ligament*) arches proximally and medially to reach the pubic tubercle, where it blends with the lacunar ligament (of Gimbernat). The *inferior cornu* (*Burns' ligament*) is also well marked, and lies just distal to the point of union of the great saphenous and femoral veins (Fig. 119). The medial border of the fossa is poorly defined. It is formed by the fascia over the pectineus, and, when traced laterally, it disappears behind the femoral sheath and blends with its posterior wall.

The fossa ovalis is 1½ inches long by half an inch wide, and is of particular importance because it represents the distal opening of the track taken by a femoral hernia after it has passed through the femoral (crural) ring (p. 408).

The lateral intermuscular septum is a strong partition which connects the deep fascia to the lateral lip of the linea aspera of the femur. It separates the vastus lateralis from the femoral head of the biceps, and thus forms a partition between the extensor and flexor compartments of the thigh. Incisions to expose the diaphysis of the femur are made in front of the line of the lateral intermuscular septum (p. 442).

The *medial intermuscular septum* separates the adductor from the extensor compartment of the thigh. As it covers the anterior surfaces of the adductor longus and magnus, it forms the fascial floor of the adductor canal (of Hunter).

The Femoral Sheath is a sleeve-like prolongation of the fascial envelope of the abdomen (p. 275) which passes down into the thigh behind the inguinal ligament. Lateral to the femoral vessels, both the fascia transversalis and the fascia iliaca are attached to the inguinal ligament; but opposite the vessels, which intervene between the two layers, they are carried into the thigh to form the femoral sheath (Fig. 120).

The sheath is described as possessing three compartments, but the arrangement is precisely the same as that already described for the carotid sheath (p. 116). The femoral artery and the lumbo-inguinal nerve lie lateral to the femoral vein. One of the deep subinguinal lymph glands lies medial to the vein surrounded by some extraperitoneal fat, the two together constituting the septum femorale (crurale). This part of the sheath is termed the femoral (crural) canal, and is of great importance because it constitutes the passage through which a femoral hernia enters the thigh.

The femoral sheath is related anteriorly to the fascia lata and the fossa ovalis; posteriorly, it rests on the pectineus, medially, and on the psoas major, laterally. Between these two muscles the posterior wall of the sheath is connected to the capsule of the hip-joint.

The mouths of the central and lateral compartments of the sheath are completely filled by their contents, but the mouth of the femoral canal, which is termed the *femoral* (*crural*) *ring*, is occupied only by a lymph gland, and therefore constitutes a weak point in the fascial envelope of the abdomen. In addition to its fascial walls, the femoral ring is bounded anteriorly by the inguinal ligament, laterally by the femoral vein, posteriorly by the pectineus and the subjacent ramus of the pubis, and medially by the free, lateral margin of the lacunar ligament (of Gimbernat).

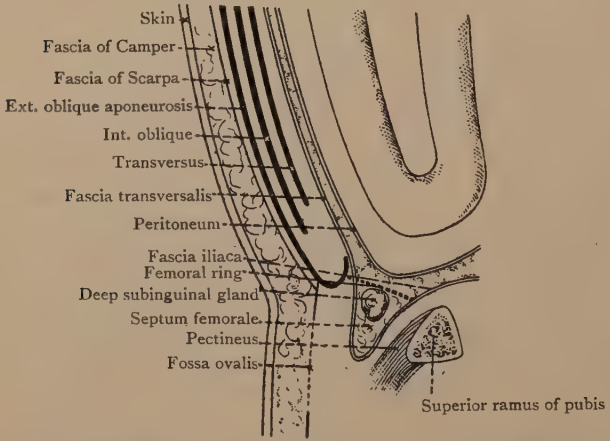
Skin
Fascia of Camper
Fascia of Scarpa
Ext. oblique aponeurosis
Int. oblique
Transversus
Fascia transversalis
Peritoneum
Fascia iliaca
Femoral ring
Deep subinguinal gland
Septum femorale
Pectineus
Fossa ovalis
Superior ramus of pubis

FIG. 120.—Diagram of a Sagittal Section through the lower part of the Abdomen and the proximal part of the Thigh. The section passes through the femoral canal and demonstrates the mode of formation of the femoral sheath.

In a **Femoral Hernia** the bowel pushes the parietal peritoneum of the lower part of the anterior abdominal wall and the extra-peritoneal fat (septum femorale, p. 407) through the femoral ring into the femoral canal. It stretches the anterior wall of the sheath and thus gains another covering. The sac, together with its coverings, passes through the fascia lata at the fossa ovalis, and then, following the course of least resistance, bends upwards towards the anterior superior iliac spine in the lax, fatty space which contains the proximal subinguinal lymph glands.

During attempts to reduce a femoral hernia the thigh should be semiflexed and slightly adducted in order to relax the pectineus, the fascia lata, and the inguinal ligament. Gentle manipulations are then carried out to make the protrusion retrace the course of its original path, first distally and medially till it passes through the fossa ovalis, and finally, backwards and proximally through the femoral ring.

The *surgical approach* may be by means of an incision parallel and just distal to the medial part of the inguinal ligament, or a semilunar incision may be utilised, the base of the flap being medial, with the object of keeping the wound as far as possible from the genitalia. After division of the skin, superficial fascia and vessels, a little blunt dissection reveals a mass of fat quite distinct from the surrounding fatty areolar tissue. The coverings derived from the fascia cribrosa and the wall of the femoral canal can rarely be identified. Further blunt dissection is carried out until the neck of the tumour is isolated at the femoral ring, and while this is being done the union of the great saphenous with the femoral vein may be exposed just proximal to the distal edge of the fossa ovalis. The fatty tissue, which consists of the septum femorale, is then carefully incised step by step in a search for the hernial sac. Sometimes there is no sac and the tumour is simply a lipoma growing in the septum femorale. If a sac is found it is carefully isolated, ligated, and transplanted upwards by carrying the long ends of the ligatures upwards through the femoral ring and bringing them out above the inguinal ligament and there tying them.

Many methods have been introduced in order to close, narrow, or obstruct the femoral canal, but owing to the rigidity of the parts above and the constant movements of the parts below, none of them have proved altogether satisfactory. A strong purse-string catgut suture may be utilised to pucker up the fascia in the region. It is passed through the inguinal ligament, the fascia lata, the lateral border of the fossa ovalis, and the fascia over the pectineus and Cooper's ligament, a strong fibrous thickening attached to the pectineal line immediately posterior to the origin of pectineus. Care must be taken not to injure the femoral vein. Or, a flap of the pectineal fascia may be dissected up and stitched to the inguinal ligament, thus closing the femoral ring.

Femoral hernia occurs more frequently in women than in men. This is partly on account of the greater width of the pelvis and the increased size of the femoral ring, and partly because the peritoneal fossa, which lies opposite the ring, is more pronounced in the female. In young girls and female infants inguinal hernia (p. 268) is the commoner variety, but after puberty femoral hernia is the commoner of the two.

Owing to the narrowness of the canal and the unyielding character of its walls, the occurrence of irreducible femoral epiplocele is not uncommon, and femoral herniæ frequently become strangulated. In operating on a *strangulated femoral hernia*, some difficulty may be experienced in recognising the sac when it is reached on account of the œdema and congestion. All the layers must be divided until the escape of the discoloured fluid from within the sac indicates the proximity of the bowel. Before the condition of the gut at the constricted neck can be examined and the hernia reduced the femoral ring must be enlarged. Owing to the nature of the boundaries of the ring (p. 408) this can only be carried out on the medial side. A director is passed along the medial side of the neck of the sac and a guarded knife is introduced. Two or three small incisions are made in the free edge of the lacunar ligament (of Gimbernat), until the opening is sufficiently enlarged to permit of the bowel being withdrawn for examination. In a very small percentage of cases this proceeding is at once followed by severe hæmorrhage, due to injury of an *abnormal obturator artery*. Normally the obturator artery (p. 416) arises from the hypogastric, but in about 20 per cent of cases it arises from the inferior (deep) epigastric (Fig. 121). In its subsequent course towards the obturator foramen it may pass either to the medial or lateral side of the femoral ring. When the artery passes medial to the ring it is apt to be injured when the lacunar ligament is incised in relieving the strangulation of a femoral hernia. If the bleeding points cannot be caught it will be necessary to cut down on and ligature the inferior epigastric artery (p. 257).

Cold abscesses originating in connection with the vertebral column or the hip-joint may give rise to a swelling in the proximal part of the thigh. As they possess an impulse on coughing, and disappear or decrease in size in the recumbent position, they may be mistaken for femoral herniæ. The point at which they emerge from behind the inguinal ligament may clear up the diagnosis, for the neck of a femoral hernia is always placed distal to the medial extremity of the ligament, whereas a cold abscess appears to the lateral side of the femoral vessels (p. 529).

The **Femoral Trigone (of Scarpa)** is a triangular space lying immediately distal to the inguinal ligament, which forms its base. Its oblique lateral boundary, formed by the sartorius, and its straight medial boundary, formed by the medial border of the adductor longus, meet one another at the apex of the triangle.

The floor of the space is formed, in its lateral part, by the iliacus and psoas major, as they cross the front of the hip-joint to reach the lesser trochanter. The medial part of the floor is formed by the pectineus proximally and the adductor longus distally (Fig. 121).

The most important contents of the space are the femoral vessels and nerve, together with their large branches.

The **Femoral (Anterior Crural) Nerve** (L. 2, 3, 4) enters the thigh by passing behind the inguinal ligament half an inch lateral to the femoral artery. In the pelvis the nerve lies deep to the fascia iliaca. In the thigh it lies in the groove between the psoas major and the iliacus, and is covered over by the fascia lata, which is usually thickened in this situation. The nerve at once breaks up into (1) cutaneous, (2) muscular, and (3) articular branches.

(1) The *medial* and *intermediate cutaneous nerves* are described on p. 405.

The *saphenous nerve* (L. 3 and 4) runs medially and distally towards the femoral artery, and at the apex of the femoral trigone it enters the adductor canal (of Hunter). It leaves the canal at its distal end and pierces the deep fascia near the adductor tubercle, where it becomes associated with the great saphenous vein. Its terminal branches are distributed to the medial side of the leg and foot (p. 504).

(2) The *muscular branches* of the femoral nerve supply the pectineus, the sartorius, and the quadriceps extensor.

(3) *Articular branches* arise from the nerves to the vasti and supply the knee-joint, while the nerve to the rectus femoris gives off a branch to the hip-joint. In addition to receiving branches from the femoral nerve, both joints are supplied by the obturator nerve (p. 416). It is not uncommon to find that, in tuberculous disease of the hip-joint, the pain is entirely referred to the knee. Whether the pain is referred to the joint or to the overlying skin, which is also supplied by branches of the femoral nerve, is by no means certain.

The **Femoral Artery** is the direct continuation of the external iliac. It enters the thigh behind the inguinal ligament at a point midway between the symphysis pubis and the anterior superior iliac spine; and its course is represented by the proximal two-thirds of the line joining this point to the adductor tubercle, when the thigh is slightly flexed, abducted, and laterally rotated.

In its proximal half the artery lies immediately behind the deep fascia covering the femoral trigone. It may be compressed against the head of the femur, but owing to the shape of the latter, this method of occluding the vessel is unreliable. The vessel is usually compressed distally and backwards against the superior ramus of the pubis, which it crosses as it enters the thigh. In cases of disarticulation at the hip-joint, where the vessel is not at once exposed and ligated, the most satisfactory method of arresting hæmorrhage is by compression of the abdominal aorta just above its bifurcation (Macewen).

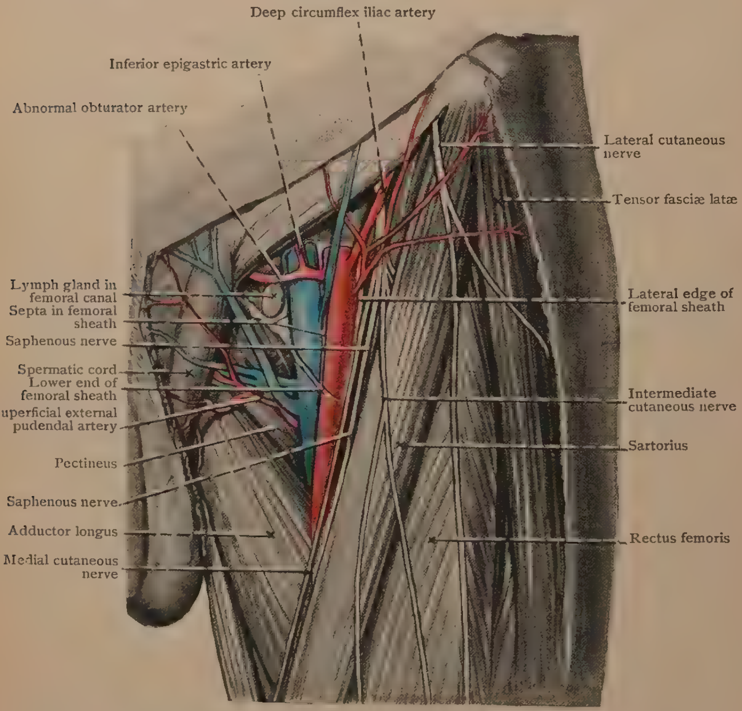
Deep circumflex iliac artery
Inferior epigastric artery
Abnormal obturator artery
Lateral cutaneous nerve
Tensor fasciæ latæ
Lymph gland in femoral canal
Septa in femoral sheath
Lateral edge of femoral sheath
Saphenous nerve
Spermatic cord
Lower end of femoral sheath
Intermediate cutaneous nerve
Superficial external pudendal artery
Sartorius
Pectineus
Saphenous nerve
Adductor longus
Rectus femoris
Medial cutaneous nerve

FIG. 121.—The Femoral Trigone (of Scarpa). The anterior wall of the femoral sheath has been removed. The inferior epigastric and the deep circumflex iliac arteries arise at a lower level than normal, and the former gives off the abnormal obturator artery.

Ligature of the femoral artery may be carried out close to its origin, for aneurism, or following wounds of the vessel, or as a preliminary step to a disarticulation at the hip-joint. The *incision* may be made in the course of the artery or at right angles to it. In the latter case the lumbo-inguinal nerve (p. 404) is usually divided, and the femoral vein, which lies medial to the artery, and the femoral nerve, which lies to its lateral side, run risk of injury. When the skin and superficial fascia have been divided, only the fascia lata and the anterior wall of the femoral sheath, which is usually adherent to it, have to be incised before the artery is exposed.

After ligature of the femoral artery at this site, *the circulation is re-established* (1) through the anastomosis of the deep circumflex iliac, from the external iliac, with the superficial circumflex iliac and the ascending branch of the lateral circumflex; and (2) through the anastomosis in the region of the quadrate tubercle (p. 424), where the gluteal branches from the hypogastric (internal iliac) anastomose with branches which arise from the femoral on the distal side of the ligature.

Axial anastomosis of the femoral artery and vein has been carried out in this situation in cases of threatened gangrene. The vessels are divided and the proximal end of the artery is sutured to the distal end of the vein, while the proximal end of the vein is similarly sutured to the distal end of the artery. In this way an endeavour is made to reverse the course of the blood-stream in the lower limb.

Ligature of the femoral artery at the apex of the femoral trigone is carried out by means of an *incision* along the line of the vessel. The sartorius is identified and retracted to the lateral side, exposing the artery just before it enters the adductor canal (of Hunter). In this situation the vessel is crossed by the medial cutaneous nerve, and the saphenous nerve may be either an anterior or a lateral relation. Although lying to the medial side of the artery in the proximal part of the thigh, the femoral vein occupies a posterior position at the apex of the trigone, and care must be taken not to injure it when passing the ligature. On this account the fibrous sheath of the artery is opened on its antero-lateral aspect.

After ligature of the artery at this site, *the circulation is re-established* by means of the anastomosis round the knee-joint (p. 450), where branches which arise from the femoral on the proximal side of the ligature communicate with others which arise on the distal side.

The **Quadriceps Femoris** acts as a powerful extensor of the knee-joint. It consists of four muscles, which are inserted into the proximal border of the patella by a common tendon. They are all supplied by the femoral nerve (L. 3 and 4).

(1) The *Rectus Femoris* arises by a straight head from the anterior inferior iliac spine, and by a reflected head, which joins the former almost at right angles, from the dorsum ilii just above the acetabulum. Near its origin the muscle lies at the bottom of the depression between the tensor fasciæ latæ and the sartorius (p. 403), and is in close relation to the anterior aspect of the capsule of the hip-joint. After it has been crossed by the sartorius the muscle becomes superficial, and it forms a well-marked elevation in the middle line of the thigh when the knee is extended.

(2) The *Vastus Intermedius* (*Crureus*) arises from the anterior and lateral aspects of the shaft of the femur. It is partially overlapped by (3) the *Vastus Lateralis* and (4) the *Vastus Medialis*. Both these muscles possess linear origins from the linea aspera and the proximal part of the shaft of the femur, but although the vastus medialis covers the medial aspect of the bone, it gets no fibres of origin from it.

At the sides of the patella the capsule of the knee-joint is greatly strengthened by tendinous expansions, which it receives from the vastus lateralis and medialis.

The *Sartorius* (p. 403) forms the lateral boundary of the femoral trigone and the roof of the adductor canal, and then descends vertically on the medial aspect of the thigh. It is inserted into the proximal part of the medial surface of the tibia. The sartorius acts as a flexor and medial rotator of the tibia, and as a flexor, abductor, and lateral rotator of the femur. It is supplied by the femoral nerve (L. 3 and 4).

Branches of the Femoral Artery.—Near its commencement the femoral artery gives off the *superficial external pudendal* (p. 257), the *superficial epigastric* (p. 257), and the *superficial circumflex iliac*. The last named runs laterally, parallel to the inguinal ligament, and terminates in the anastomosis around the anterior superior iliac spine (p. 421).

The **Deep External Pudendal Artery** runs medially in front of the femoral vein and the pectineus to supply the skin of the scrotum.

The **Profunda Femoris** usually arises about 1½ inches distal to the inguinal ligament, and descends at first lateral and then posterior to the femoral vessels. At the upper border of the adductor longus the profunda leaves the femoral vessels by passing behind the muscle.

The profunda gives origin to several important branches.

1. The **Lateral Circumflex**, which sometimes arises from the femoral, springs from the profunda close to its origin. It passes laterally, deep to the rectus and sartorius, where it is exposed in the anterior route for excision of the hip (p. 439), and then breaks up into: (*a*) an *ascending* branch, which joins the anastomosis round the anterior superior spine of the ilium (p. 421); (*b*) a *transverse* branch, which helps to form the crucial ana-

stomosis (p. 423); and (*c*) a *descending* branch, which joins the anastomosis round the knee-joint.

2. The **Medial Circumflex,** which frequently arises from the femoral, takes origin opposite the lateral circumflex, and runs backwards between the pectineus and the psoas major. It passes below the neck of the femur and ends in the crucial anastomosis (p. 423).

3. The **four perforating arteries** arise from the profunda more distally. They wind round the back of the femur, giving off branches to the adductors, and gain the back of the thigh. There they form a series of anastomotic arches with one another. In addition, the first perforating joins the crucial anastomosis (p. 423), and the fourth, which is the terminal branch of the profunda, anastomoses freely with branches from the popliteal (p. 450).

The **Pectineus** arises from the superior ramus of the pubis, and passes laterally and distally to be inserted into the posterior aspect of the proximal part of the shaft of the femur. It is supplied by the femoral nerve (L. 2 and 3), and acts as an adductor and flexor of the thigh.

The **Adductor group** consists of four muscles, and they are all supplied by the *obturator nerve* (L. 2, 3, 4).

1. The **Gracilis** is a thin, flattened muscle which extends from the margin of the pubic arch along the medial side of the thigh. As it is inserted into the proximal part of the tibia near the semitendinosus (p. 446), it acts more powerfully as a flexor of the knee than as an adductor of the hip. In paralysis of the ham-strings, flexion of the knee-joint is carried out satisfactorily by the gracilis, assisted by the sartorius.

2. The **Adductor Longus** (p. 403) helps to form the floor of the femoral trigone and the posterior wall of the adductor canal, and consequently supports the femoral artery in a considerable part of its course. It is the most anterior of the three principal adductors, and is inserted into the linea aspera.

3. The **Adductor Brevis** lies behind the upper part of the adductor longus. It extends from the front of the pubis to the back of the femur. Its upper border is in contact with the outer surface of the obturator externus.

4. The **Adductor Magnus** is the largest and most posterior of the three principal adductors. It arises from the margin of the pubic arch and from the lower part of the ischial tuberosity. The upper fibres are horizontal and reach the femur just distal to the quadrate tubercle; the lower fibres are almost vertical, and are inserted into the adductor tubercle (p. 448); the other fibres extend obliquely to the linea aspera and the medial supracondylar ridge. By reason of its vertical fibres, the muscle possesses a secondary action as an extensor of the hip-joint. In its upper part the anterior surface of the magnus is covered by the brevis, but below the lower border of that muscle it is in contact with the longus, and, below the longus, the magnus forms the posterior wall of the adductor canal. In the latter part of its extent it possesses a large gap, the hiatus tendineus, which transmits the femoral vessels to the popliteal fossa.

The adductor magnus receives an additional nerve-supply from the sciatic (L. 4, 5, and S. 1).

The **Obturator Externus** arises from the outer surface of the obturator membrane and the medial margin of the foramen, and its tendon passes laterally, to be inserted into the trochanteric fossa. It lies deeply in the interval between the quadratus femoris and the inferior gemellus, and is at first below and then posterior to the capsule of the hip-joint. It is supplied by the posterior branch of the obturator nerve (L. 3 and 4), and acts as a powerful lateral rotator of the thigh.

Owing to the tilt of the pelvis, the outer surface of the muscle is directed distally, laterally, and forwards. It is in relation to the pectineus and the adductor brevis.

The **Obturator Nerve** (L. 2, 3, 4) breaks up into an anterior and a posterior division as it enters the upper part of the obturator foramen. The *anterior division* leaves the pelvis above the obturator externus, and passes distally, first between that muscle and the pectineus, and then between the adductors brevis and longus. It supplies the two last-named muscles and the gracilis, and in addition gives an articular branch to the hip-joint. Further, it gives origin to a small branch which unites with a similar branch from the medial cutaneous to form the sartorial plexus. Twigs from this plexus, which lies deep to the sartorius, supply the skin on the medial side of the thigh.

The *posterior division* pierces the upper part of the obturator externus, which it supplies, and descends on the deep surface of the adductor brevis. It supplies the adductor magnus and gives off a fine articular branch to the knee-joint (p. 411).

The **Obturator Artery** (p. 410) accompanies the anterior division of the obturator nerve through the foramen. It divides into two branches, which encircle the obturator membrane deep to the obturator externus, supplying the muscle and giving off a branch to the hip-joint.

Obturator Hernia is of rare occurrence. It follows the vessels and nerve through the upper part of the obturator foramen but has no constant relation to them. The protrusion, however, causes pressure on the nerve and gives rise to *Romberg's symptom.* This consists in tenderness of the adductors, and pain referred to the cutaneous distribution of the obturator nerve on the medial side of the thigh.

The hernia, which is usually strangulated, lies behind the pectineus and on the surface of the obturator externus, causing a small, ill-defined swelling in the medio-proximal part of the thigh ; the thigh is kept flexed in order to relax the pectineus, and attempts to produce extension cause severe pain. Adduction is also resisted, as this movement tends to squeeze the hernia against the obturator externus.

The **Adductor Canal (of Hunter)** is an intermuscular space on the medial side of the middle third of the thigh, and it contains the femoral artery and vein and the saphenous nerve. The *roof* of the canal is formed by the sartorius and a strong layer of deep fascia, which lies behind the muscle. The *lateral wall* is formed by the vastus medialis, while the *posterior wall* is formed by the adductor longus proximally and the adductor magnus distally. At the distal end of the canal there is a wide gap in the insertion of the latter muscle, and through this opening, which is termed the *hiatus tendineus*, the femoral artery enters the popliteal fossa.

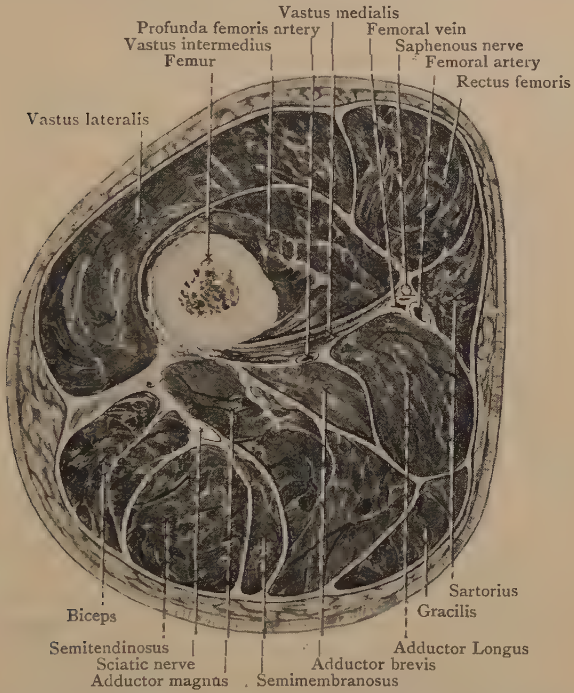
Vastus medialis
Profunda femoris artery
Femoral vein
Vastus intermedius
Saphenous nerve
Femur
Femoral artery
Rectus femoris
Vastus lateralis
Sartorius
Gracilis
Biceps
Semitendinosus
Adductor Longus
Sciatic nerve
Adductor brevis
Adductor magnus
Semimembranosus

FIG. 122.—Transverse Section through the Thigh, a little distal to the junction of the proximal and middle thirds. The lateral intermuscular septum is well shown, and the femoral vessels are seen in the adductor canal (of Hunter).

It may be necessary *to ligature the femoral artery in the* *adductor canal* following stab wounds or in cases of popliteal aneurism. The *incision* is made in the line of the vessel, and as it is deepened through the superficial fascia, the great saphenous vein or one of its tributaries may require to be retracted. The deep fascia over the sartorius is very thin, and when it has been divided the muscle may be recognised by the direction of its fibres. After the sartorius has been retracted medially the strong fascial roof of the canal is incised, and the femoral artery is exposed with the saphenous nerve on its anterior surface. The femoral vein lies posterior to the artery in the proximal part of the canal, but distally it inclines to the lateral side. In passing the aneurism needle care must be taken to avoid injuring the vein.

After ligature of the femoral artery in the adductor canal, the *collateral circulation* is re-established (1) through the anastomosis between the descending branch of the lateral circumflex (p. 414) and the arteria genu suprema (anastomotica magna), and (2) through the anastomosis between the fourth perforating artery (p. 415) and branches of the popliteal (p. 450).

The *arteria genu suprema* arises from the femoral just before it leaves the adductor canal. It divides into a saphenous branch, which becomes superficial, and an articular branch. The latter enters the vastus medialis and descends on the femur to take part in the anastomosis around the knee-joint (p. 450).

THE GLUTEAL REGION.

Bony Landmarks.—The *ischial tuberosity* lies vertically below the posterior superior iliac spine. It is deeply situated under cover of the glutæus maximus when the thigh is extended; and when the thigh is flexed, although the muscle slips over the tuberosity, the skin and fasciæ are no longer relaxed, so that the recognition of this bony point becomes more difficult.

The *greater trochanter* of the femur lies a hand-breadth below the tubercle on the iliac crest (p. 241). In a normal subject its position is indicated by a flattened depression on the lateral aspect of the proximal part of the thigh, but in wasted subjects it becomes a very prominent projection. Its lateral aspect is about two inches long by 1½ inches wide, and its margins, more especially the posterior, can readily be felt when the deep fascia, which tends to obscure them, is relaxed by passively abducting the thigh. When the limb is in this position the fingers can sink into the trochanteric (digital) fossa posteriorly, but this depression is occluded in fractures in this neighbourhood. The greater trochanter may become distorted, following its implication in fractures or infective disease. Increase in size can be determined and the two sides compared by encircling both prominences with the fingers and thumbs.

The *lesser trochanter* can be felt by palpating deeply beneath the gluteal fold in the medial aspect of the thigh, when the limb is extended and medially rotated.

The *iliac crests* and *spines* have been described on pp. 241, 243.

The **Muscular Landmarks** of the buttock are obscured by the thick fatty superficial fascia, but the outline of the *glutæus maximus* can sometimes be seen. Its lower border crosses the centre of the *gluteal fold* obliquely downwards and laterally, and disappears in the general contour of the lateral aspect of the thigh. The upper border of the muscle descends obliquely from the posterior part of the iliac crest towards the apex of the greater trochanter. When the thigh is actively rotated medially, a muscular elevation at once appears just below and lateral to the anterior superior iliac spine. It consists of the *tensor fasciæ latæ* superficially and the *glutæus minimus* deeply.

The **Cutaneous Nerves** of the buttock are derived from numerous sources. (1) The terminal branches of the *posterior rami of L. 1, 2, and 3* cross the iliac crest lateral to the sacro-spinalis, and may descend as far as the gluteal fold. (2) The *lateral branches of the ilio-hypogastric* (*L. 1*) *and last thoracic nerves* (p. 244) cross the crest at the iliac tubercle and supply the skin of the adjoining area. (3) Branches from the *lateral cutaneous nerve* of the thigh (L. 2 and 3) pass backwards into the gluteal region. (4) The *posterior cutaneous* (*small sciatic*) (*S. 1, 2, and 3*) gives off recurrent branches, which ascend over the lower border of the glutæus maximus. (5) The skin near the middle line is supplied by *branches of S. 1, 2, and 3* (Fig. 124).

Referred pain in the region of the buttock may occur in inflammatory conditions of the lower part of the pleura (lateral cutaneous branch of T. 12) or in irritative conditions of the bladder and rectum (posterior cutaneous, S. 1, 2, and 3).

The **Deep Fascia** of the buttock is attached above to the iliac crest. In its antero-superior part, where it covers the glutæus medius, it is a strong fibrous sheet, but it splits at the upper border of the maximus into two much weaker layers, which enclose the muscle. On the lateral aspect of the buttock these two layers increase in strength, and having received the insertion of the greater part of the glutæus maximus, they reunite to form the strong ilio-tibial tract (p. 406). A linear thickening is sometimes present on the deep aspect of the ilio-tibial tract, extending downwards from the iliac crest just behind the posterior border of the greater trochanter. It is relaxed during abduction, but is taut in adduction of the hip. When it is present, the thickening is at first stretched by the apex of the trochanter as it passes backwards on flexion of the thigh, particularly if the limb is also adducted, and then it suddenly slips forwards over the bony prominence with an audible click. The condition is termed " snapping-hip " and may be controlled by a pad exerting pressure immediately behind the trochanter.

The **Glutæus Maximus** passes distally and laterally from the posterior part of the iliac crest and the dorsum of the sacrum to its insertion into the deep fascia and the gluteal tuberosity of the femur. It is supplied by the inferior gluteal nerve (L. 5, S. 1 and 2) and acts as an extensor, abductor, and lateral rotator of the thigh. Owing to the great bulk of the muscle, it is extremely difficult to determine fluctuation under cover of it. The fasciculi of which it is made up are very coarse and can readily be separated without damage. They run distally and laterally, and incisions into the buttock are therefore made in the same direction. A layer of fat underlies the glutæus maximus, and it may be the site of cellulitic infection following intra-pelvic or ischio-rectal abscesses. The infection spreads through the greater or lesser sciatic foramen, and it penetrates the parietal pelvic fascia, which closes the foramina, by tracking along the gluteal and the internal pudendal vessels (p. 422). A large and constant *bursa* intervenes between the muscle and the ischial tuberosity, and when inflamed gives rise to a painful swelling. Such a bursitis requires to be differentiated from a gumma and from a cold abscess (p. 529), which may both occur in this situation.

Two other *bursæ* are found near the insertion of the muscle, one between its fascial insertion and the greater trochanter (p. 438) and the other between its tendon and the vastus lateralis. They are both liable to tuberculous synovitis, and the resulting cold abscess may spread (1) distally along the lateral surface of the thigh under the fascia lata or (2) backwards and distally under the glutæus maximus to point in the gluteal fold.

These bursæ are frequently infected with tuberculous disease and may be *approached* by a U-shaped *incision*. The anterior limb of the incision lies behind the posterior border of the tensor fasciæ latæ, and the posterior limb divides the proximal part of the insertion of the glutæus maximus. The transverse part of the incision lies distal to the greater trochanter. Free exposure is necessary, as the bursæ when diseased may possess extensive prolongations.

The glutæus maximus covers most of the dorsum ilii and the muscles, to which it gives origin, and both the sacro-tuberous and the sacro-spinous (greater and lesser sacro-sciatic) ligaments. In addition, it covers both the greater and lesser sciatic foramina and the vessels and nerves which they transmit (Fig. 123).

The **Piriformis** (p. 359) emerges from the greater sciatic foramen, and, as it passes laterally to the apex of the greater trochanter, it lies on the postero-superior aspect of the capsule of the hip-joint. It abducts the thigh, and receives its nerve-supply from S. 1 and 2.

The **Glutæus Medius** is exposed above the upper border of the maximus, but its posterior part is covered over by that muscle. It arises from the dorsum ilii, and is inserted into an oblique ridge which runs forwards and distally across the lateral aspect of the greater trochanter. The lower or posterior border of the medius lies along the upper border of the piriformis.

The **Glutæus Minimus** arises from the dorsum ilii, under cover of the medius. As it passes to its insertion on the anterior aspect of the greater trochanter, the muscle is closely related to the superior aspect of the capsule of the hip-joint.

Both the glutæus medius and minimus act as powerful abductors of the thigh, but, in addition, their anterior fibres, which lie deep to the tensor fasciæ latæ, assist in medial rotation. The nerve-supply to both muscles is derived from the superior gluteal (L. 4 and 5, S. 1).

The **Superior Gluteal Artery**, a branch of the hypogastric (p. 373), enters the buttock through the greater sciatic foramen between the adjoining borders of the piriformis and the glutæus medius. It possesses a short trunk, which divides into a *superficial* and a *deep division*. The former enters the maximus and the latter breaks up into upper and lower branches, which pass laterally between the medius and the minimus.

The upper branch terminates in the region of the anterior superior iliac spine, where it anastomoses with the superficial and deep circumflex iliac arteries (p. 257) and the ascending branch of the lateral circumflex. This anastomosis constitutes a connection between the hypogastric (internal iliac) and the external iliac trunks (p. 413).

The superior gluteal artery may require to be *ligated* either for aneurism or following stab wounds in the buttock. The *incision* is made parallel to the fibres of the glutæus maximus, and its centre lies at the junction of the upper and middle thirds of the line joining the posterior superior iliac spine to the greater trochanter. Owing to the depth at which the vessel lies and the shortness of its main trunk, the incision should be a fairly large one.

The **Superior Gluteal Nerve** (L. 4, 5, S. 1) accompanies the artery, and supplies the glutæus medius and minimus and the tensor fasciæ latæ.

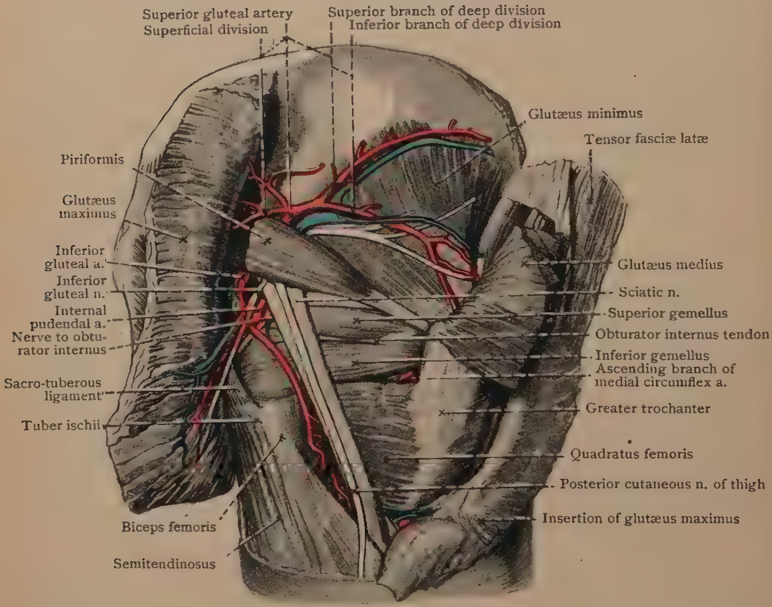
Superior gluteal artery
Superficial division
Superior branch of deep division
Inferior branch of deep division
Glutæus minimus
Tensor fasciæ latæ
Piriformis
Glutæus maximus
Inferior gluteal a.
Inferior gluteal n.
Internal pudendal a.
Nerve to obturator internus
Sacro-tuberous ligament
Tuber ischii
Glutæus medius
Sciatic n.
Superior gemellus
Obturator internus tendon
Inferior gemellus
Ascending branch of medial circumflex a.
Greater trochanter
Quadratus femoris
Posterior cutaneous n. of thigh
Insertion of glutæus maximus
Biceps femoris
Semitendinosus

FIG. 123.—The Gluteal Region. The glutæus maximus has been divided, and the glutæus medius has been removed from its origin and turned down.

Several important structures leave the pelvis through the greater sciatic foramen at the lower border of the piriformis. They include (1) the sciatic nerve, (2) the posterior cutaneous (small sciatic) nerve of the thigh, (3) the pudendal nerve, (4) the nerve to obturator internus, (5) the inferior gluteal nerve, (6) the inferior gluteal (sciatic) vessels, and (7) the internal pudendal vessels.

The pudendal nerve, internal pudendal vessels, and the nerve to obturator internus cross the spine of the ischium and pass through the lesser sciatic foramen to enter the ischio-rectal fossa (p. 377). The vessels may be injured in stab wounds, and can be exposed by an incision parallel to the fibres of the glutæus maximus, and cutting the line joining the posterior superior iliac spine to the ischial tuberosity at the junction of its lower and middle thirds.

The **Sciatic Nerve** (L. 4, 5, S. 1, 2, 3) emerges below the piriformis and passes distally, lying successively on the ischium, the obturator internus and gemelli, and the quadratus femoris. At the lower border of the quadratus it passes on to the posterior surface of the adductor magnus, and is crossed superficially by the long head of the biceps femoris, which is running distally and laterally (Fig. 123).

In intractable cases of sciatica the nerve may be *stretched* by open operation. The *incision* is carried vertically along the thigh, from the mid-point of the line joining the ischial tuberosity to the greater trochanter. After division of the skin and fasciæ, the lower border of the glutæus maximus and the biceps tendon, which runs distally and laterally, are exposed. The finger is passed into the angle between the two in a medial direction, and the nerve is hooked up from under cover of the biceps.

The **Inferior Gluteal (Sciatic) Artery** appears at the lower border of the piriformis and at once breaks up into numerous branches. It can be exposed by the incision already described for the ligature of the internal pudendal artery.

The crucial anastomosis occurs in the region of the quadrate tubercle. Branches of the inferior and superior gluteal arteries, which both arise from the hypogastric (internal iliac), anastomose with branches of the medial and lateral circumflex arteries and the first perforating, which arise from the profunda femoris. In this way an important connection is formed between the external iliac and the hypogastric trunks, and it is capable of re-establishing the circulation in the lower limb, when the external iliac is ligatured or when the femoral artery is tied proximal to the origin of its profunda branch (p. 412).

The **Posterior Cutaneous (Small Sciatic) Nerve** of the thigh (S. 1, 2, and 3) runs distally, under cover of the glutæus maximus and on the surface of the sciatic nerve. At the lower border of the maximus the nerve crosses the biceps superficially, and continues its course through the thigh immediately under the deep fascia and in the middle line of the limb. It gives off twigs to supply the skin of the buttock and of the posterior and medial aspects of the thigh (Fig. 124).

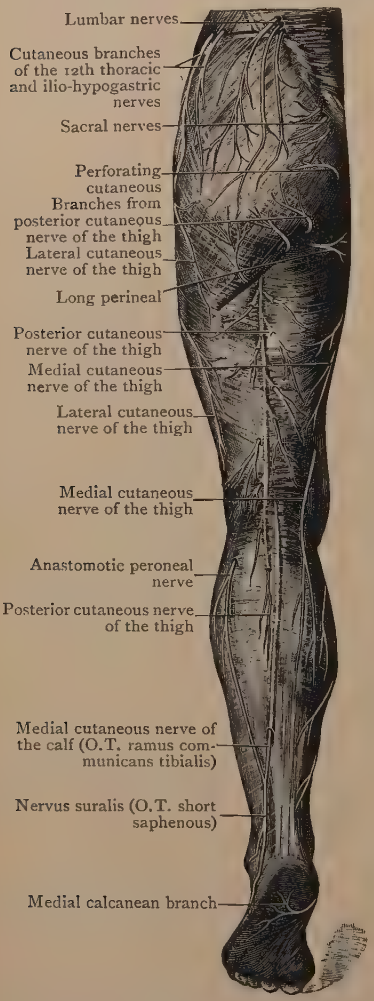
Lumbar nerves
Cutaneous branches of the 12th thoracic and ilio-hypogastric nerves
Sacral nerves
Perforating cutaneous
Branches from posterior cutaneous nerve of the thigh
Lateral cutaneous nerve of the thigh
Long perineal
Posterior cutaneous nerve of the thigh
Medial cutaneous nerve of the thigh
Lateral cutaneous nerve of the thigh
Medial cutaneous nerve of the thigh
Anastomotic peroneal nerve
Posterior cutaneous nerve of the thigh
Medial cutaneous nerve of the calf (O.T. ramus communicans tibialis)
Nervus suralis (O.T. short saphenous)
Medial calcanean branch

FIG. 124.—The Cutaneous Nerves on the Posterior Aspect of the Lower Limb.

Herniæ may escape from the pelvis through the greater sciatic foramen and appear at the upper or lower border of the piriformis. They are known as superior or inferior *gluteal herniæ*. The former variety is the less uncommon, and it occurs more often in the female and on the right side of the body. The neck of the sac lies in the fossa ovarica (p. 397) in the angle between the obturator and the hypogastric arteries. If the hernia becomes strangulated, the constriction at the neck should be divided in a downward and lateral direction, parallel to the fibres of the piriformis.

The tendon of the *obturator internus* (p. 359) leaves the pelvis through the lesser sciatic foramen and passes laterally to the greater trochanter. The superior and inferior gemelli are attached to its upper and lower margins. This tricipital tendon, which abducts the thigh and rotates it laterally, is closely related to the posterior aspect of the capsule of the hip-joint. The obturator internus is supplied by a special branch from the sacral plexus (L. 5, S. 1, 2).

The *quadratus femoris* is placed at a slightly lower level. Its fibres are practically horizontal and extend from the ischial tuberosity to the quadrate tubercle on the intertrochanteric crest (posterior intertrochanteric line), so that the muscle acts as a lateral rotator and also as an adductor. It receives a special branch from the sacral plexus (L. 4, 5, S. 1).

The **Hip-Joint** is formed by the articulation of the rounded head of the femur with the cup-shaped acetabulum on the lateral aspect of the hip-bone. The ilium, ischium, and pubis all share in the formation of the acetabulum, and *at birth* they are separated from one another by a triradiate bar of cartilage. Secondary centres of ossification appear in this cartilage about the twelfth year, and the acetabulum is completely ossified by the sixteenth or seventeenth year (Fig. 126).

The articular cartilage forms a broad strip round the acetabulum near its circumference, but the floor of the cavity and the acetabular (cotyloid) notch are non-articular.

At birth the proximal end of the femur is entirely cartilaginous. The neck of the femur is ossified by a proximal extension from the diaphysis, and, as it forms, it divides the cartilaginous extremity into two parts, which it separates from one another. The more proximal of these forms the head. A centre of ossification appears in it during the first year, and it unites with the neck during the twentieth year. The more distal forms the greater trochanter, which begins to ossify in the second year and joins the shaft at 19. The secondary centre for the lesser trochanter, which unites with the shaft at 18, does not appear till the eighth to the twelfth year.

The articular head of the femur forms rather more than half a sphere. A little below and behind its centre there is a non-articular depression for the attachment of the ligamentum teres.

The **Labrum Glenoidale** (cotyloid ligament) is a strong fibro-cartilaginous ring attached to the circumference of the acetabulum, and serving both to deepen its cavity and to reduce the diameter of its inlet. It is accurately fitted round the head of the femur, and even after the joint has been opened it is not easy to pull the head of the femur out of the acetabulum.

The **Transverse Ligament** bridges across the acetabular notch, and completes the circumference of the acetabulum.

The **Capsule** of the hip-joint is of great strength. Proximally, it is attached to the bony circumference of the acetabulum, the labrum glenoidale, and the transverse ligament (Fig. 125). Distally, it is attached to the neck of the femur; anteriorly, this attachment is along the intertrochanteric line; but posteriorly, it crosses the middle of the femoral neck—*i.e. the whole of the anterior surface and the medial half of the posterior surface of the femoral neck lie within the capsule.*

The capsule is strengthened by certain accessory ligaments.

1. The **Ilio-Femoral Ligament** is a well-marked thickening of the anterior aspect of the capsule. It is attached proximally to the anterior inferior iliac spine, just below the origin of the straight head of the rectus femoris. Distally it divides into two parts, which are respectively attached to the upper and lower portions of the intertrochanteric line.

The medial, longer limb of the ilio-femoral ligament sustains the forward pressure of the femoral head when the body is in the erect attitude, and prevents hyperextension of the joint. The shorter, lateral limb prevents too great a degree of adduction and lateral rotation, as these movements render it tense.

2. The **Pubo-Capsular Ligament** strengthens the infero-medial part of the capsule. It becomes tense during the movement of abduction.

3. The **Ischio-Capsular Ligament** is a much weaker band, which is placed in relation to the posterior aspect of the capsule. It helps to prevent too great a degree of medial rotation.

Although it is usually complete, the capsule is occasionally interrupted by a communication between the joint cavity and the bursa under the psoas major (p. 277). This opening lies between the medial limb of the ilio-femoral and the pubo-capsular ligament.

The *ligamentum teres* is intra-capsular but extra-synovial. It is attached distally to the head of the femur and proximally to the transverse ligament and the edges of the acetabular notch. It is completely surrounded by a tube of synovial membrane (Fig. 125).

The **Synovial Membrane** of the hip-joint covers the deep surface of the capsule, and at the distal attachment of the latter is reflected on to the femoral neck, where it is thrown into numerous parallel ridges, known as the retinacula. At the attachment of the capsule to the transverse ligament, the synovial membrane forms a tube round the ligamentum teres and also covers the pad of fat (*Haversian gland*) which occupies the floor of the acetabulum (Fig. 125).

Spread of Tuberculous Disease in the Region of the Hip-Joint.—Tuberculous disease in the region of the hip-joint commences most frequently in the *neck of the femur*, near its lower surface, and close to the epiphyseal cartilage of the head of the bone. It is in the first place extra-synovial but intra-capsular, and, on this account, infection of the hip-joint occurs with great frequency. As the disease progresses it reaches the surface of the bone, destroys the periosteum, and invades the synovial membrane. These changes are usually accompanied by a reactionary effusion within the joint. If this effusion occurs early in the disease, adhesions may form between the synovial membrane of the femoral neck and that lining the capsule and delay the extension of the disease into the joint. Such adhesions give rise to limitation of movement,

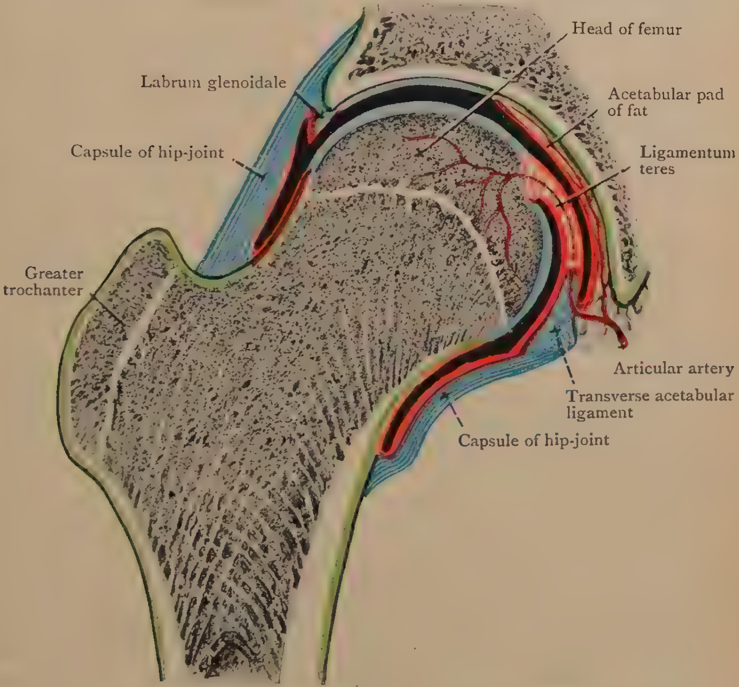
Head of femur
Labrum glenoidale
Acetabular pad of fat
Capsule of hip-joint
Ligamentum teres
Greater trochanter
Articular artery
Transverse acetabular ligament
Capsule of hip-joint

FIG. 125.—Oblique Section through Right Hip-Joint, showing the relation of the Capsule to the Epiphysis of the Head of the Femur.

Light blue = articular cartilage.
Striped blue = ligaments.
Green = periosteum.
Red = synovial membrane.

which may be the first sign of the disease. In the absence of adhesions, the disease rapidly becomes intra-synovial and attacks the articular cartilage.

If the disease spreads across the neck it may actually separate the head or render it so weak that a diastasis readily occurs. Only very exceptionally does the disease perforate the epiphyseal cartilage and invade the epiphysis from without the joint.

Tuberculous disease may originate in any of the three component parts of the *acetabulum* (p. 425), and in this case the spread to the joint is prevented only by the articular cartilage, *i.e.* no epiphysis intervenes between the joint cavity and the tuberculous focus.

The *diaphyseal side of the epiphysis for the greater trochanter* constitutes a third site for the occurrence of tuberculous disease in this region. Spread may take place (*a*) down the shaft, as an osteo-myelitis; (*b*) along the neck, ultimately involving the joint; or (*c*) through the periosteum in front of or behind the trochanter, giving rise to abscess and sinus formation. Tuberculous abscesses in the region of the hip, however, much more commonly have their origin within the joint.

When the disease becomes intra-synovial the pus eventually perforates the capsule at its weakest points, which are found (1) postero-laterally, and (2) anteriorly, between the ilio-femoral and pubo-capsular ligaments.

1. After perforating the postero-lateral part of the capsule the pus gravitates distally and backwards to point near the gluteal fold, but it occasionally travels forwards deep to the glutæus maximus and the tensor fasciæ latæ to point in the interval between the latter muscle and the sartorius (p. 403).

2. The course taken by pus, after perforating the anterior aspect of the capsule, is by no means constant. (*a*) If the joint cavity communicates with the psoas bursa (p. 277) the pus ascends within the bursa to the iliac fossa and the pelvis. It may here be pointed out that a psoas abscess may infect the bursa, and, spreading in the opposite direction, may involve the hip-joint. (*b*) The pus may gravitate along the tendon of the psoas major and then follow the course of the medial circumflex artery (p. 415). It reaches the dorsum above the upper border of the adductor magnus and points in the gluteal fold. (*c*) Sometimes, after following the psoas major tendon, the pus passes laterally along the lateral circumflex artery and reaches the surface in the gluteal fold or in the neighbourhood of the

greater trochanter. In the former case, the condition has to be diagnosed from a tuberculous infection of the bursæ underlying the tendon of the glutæus maximus.

3. More rarely the pus perforates the inferior aspect of the capsule, and at once comes into relation with the obturator externus (p. 415). By following this muscle to its insertion the pus again reaches the gluteal fold, but if it tracks in the opposite direction it comes to the surface on the proximo-medial part of the thigh.

Intra-Pelvic Spread.—When tuberculous disease originates in the acetabulum, it may not only infect the joint but it may spread inwards to the pelvis. The course taken by the pus in the latter case depends on whether it pierces the pelvic wall above or below the line of origin of the levator ani (p. 360). In the former case the pus pierces the parietal pelvic fascia and lies in the subperitoneal areolar tissue. It may track along the rectum, or it may fill up the pelvis till it overflows through the obturator foramen or escapes into the thigh behind the inguinal ligament. When it pierces the pelvic wall below the line of origin of the levator ani, the pus at once gains the ischio-rectal fossa and gravitates downwards to point near the anus.

Owing to the possibility of intra-pelvic spread, digital examination of the pelvis should be carried out *per rectum* in every case of tuberculous disease of the hip-joint.

Aspiration of the Hip-Joint can be carried out by introducing an exploring needle upwards, backwards, and medially at a point 2 to 2½ inches distal to the anterior inferior iliac spine. The instrument gains the interior of the joint by passing under the lateral border of the rectus femoris and piercing the distended capsule.

The following *lines* and *measurements* are of value in the examination of the region of the hip-joint.

The line joining the highest parts of the two greater trochanters passes through the centres of the two acetabula. The head of the femur lies behind the point of intersection of this line and the produced lateral line of the abdomen.

Nelaton's line, which joins the anterior superior iliac spine to the ischial tuberosity, passes through the highest part of the greater trochanter. When the trochanter is found to lie above or below that line some deformity of the neck of the femur must be present. The difficulty of accurate localisation of the ischial tuberosity minimises the value of this method of examination.

Chiene demonstrated the symmetry or asymmetry of the trochanters by comparing the line joining their highest points with the line joining the anterior superior spines. This method is of service when the deformity is unilateral, as the lines are then no longer parallel, but it may fail to indicate a bilateral deformity.

Bryant's method involves the measurement of the vertical distance between the highest point on the greater trochanter and the horizontal plane passing through the anterior superior iliac spines. This distance is normally about two inches. Asymmetry points to unilateral deformity and symmetrical measurements, with marked deviation from the normal two inches, to bilateral deformity.

A comparison of the length measurements of the two limbs is of great value to the surgeon in relation to injury or disease in the region of the hip. Before proceeding with the actual measurements, it is very important to see that the pelvis is not tilted to one side and to make certain that the patient's limbs are both in exactly the same position. To discover any lateral tilting of the pelvis, a line is drawn from the anterior superior spine of the ilium at right angles to the linea alba, and this, when produced, should pass through the anterior superior spine of the other side.

Measurements should be taken from the anterior superior spine to the distal margin of the medial condyle of the femur and from that point to the medial malleolus, and these measurements should be compared with those obtained on the opposite limb. From this comparison any inequality of the two limbs can be referred to the bone at fault, either the femur or the tibia as the case may be, and this method is therefore of much greater value than the direct measurement from the anterior superior spine to the medial malleolus. When femoral shortening is discovered, the deformity can be referred to the shaft or the neck by comparing the measurements from the tips of the greater trochanters to the distal borders of the lateral condyles. If these are found to be equal, the deformity must be in the femoral neck. Shortening of the femoral or tibial shaft may arise as a result of infantile paralysis.

It is by no means unusual for the length measurements to show trifling differences, and, unless this exceeds half an inch, no stress should be laid on it.

The measurements are usually carried out with the patient in the dorsal decubitus, and care must be taken to see that the limbs have the same position relative to the trunk as they have in the erect attitude. This precaution is essential, as the distance between the anterior superior spine and the medial condyle is definitely shorter in abduction than it is in adduction of the thigh. Hence if the diseased limb is abducted, it is shortened, and if the sound limb is adducted so as to be parallel to it, it is lengthened proportionately. The difference between the length measurements will, therefore, be very considerable.

A convenient method of comparing the lengths of the lower limbs can be used in children. The patient is placed on his back, and care is taken to see that the limbs are symmetrically disposed and that the pelvis is not tilted. With the knees extended, the thighs are semi-flexed at the hips so that the soles point upwards. The relative positions of the heels are at once demonstrated.

Examination of the Hip-Joint and Proximal Extremity of the Femur.—The patient should be completely stripped and asked to walk if possible, as the gait may be of assistance in determining the diagnosis. Any limitation of active movement, the presence of a limp or lurch, and the way in which the feet are placed on the ground should all be observed with great care.

After this inspection the patient should be placed on his back on a hard, firm surface. The bony prominences on each side can then be carefully marked, and while this is being done palpation and comparison of the trochanters may be carried out and the position of the femoral head may be determined. The measurements of both limbs are next taken and the various lines (p. 429) may be utilised.

Lastly, the extent and nature of passive movements must be examined. These movements, which comprise flexion, extension, abduction, adduction, circumduction, and rotation, are first carried out on the healthy limb in order to test their normal extent and to gain the confidence of the patient. Next the movement of hyperextension is tested, with the patient in the prone position. The pelvis is fixed by a hand placed on the sacrum ; and the other hand, placed under the thigh, hyperextends the limb by lifting it from the table. Differences in the extent of symmetrically arranged passive movements, with or even without differences in length measurements, are most valuable in diagnosis.

The use of radiograms has made the diagnosis of disease or injury in the region of the hip-joint much more certain.

Function of the Hip-Joint.—In contradistinction to the shoulder-joint, where free mobility is the first essential, the chief characteristic of the hip-joint is its stability. Consequently, in the treatment of pathological conditions of the joint, the chief aim of the surgeon is to obtain a stable joint. If a movable joint can be obtained at the same time, the result will be so much the better, but mobility without stability is of no value.

The weight of the trunk is transmitted to the femoral heads through the upper parts of the acetabula, and thence is transmitted down the limbs to the ground.

In order to increase the power and mobility of the lower limb and to distribute the weight of the body over a wider base, the neck of the femur is inclined to the shaft at an angle which varies from 160° in the child to 110° in the adult, *i.e.* with the constant increase in body-weight the angle deviates more and more from 160°.

Abnormal alterations of the angle may seriously interfere with the mobility of the hip-joint. In cases of early extensive infantile paralysis of the lower limb, and in congenital dislocation of the hip, the angle remains of the infantile type, since the head and neck of the femur are not used to support their share of the body-weight. This condition is known as *coxa valga.*

In constitutional diseases, such as rickets, and following injuries to the neck of the femur during infancy, the body-weight acting on softened bone produces an abnormal decrease of the angle, which in some cases may be reduced to 45°. This condition is termed *coxa vara.*

Abduction of the thigh is markedly limited in coxa vara, as the greater trochanter impinges too soon on the ilium. In coxa valga, on the other hand, abduction is a very free movement, but adduction is correspondingly limited.

Injuries of the Neck of the Femur.—In the *infant,* the cartilaginous proximal extremity of the femur, which includes both the head and the neck, may be fractured. The injury often occurs in the following way. When an infant, held in the nurse's arms, throws itself backwards, the weight of its body stretches the strong ilio-femoral ligament across the anterior surface of the head of the femur. If the child's limbs were not held by the nurse the pull of the body-weight on the ligament would flex the thigh and relieve the strain, but as the limbs are firmly held, the cartilaginous neck of the femur gives way, since the ilio-femoral ligament is too strong to yield.

In the *child*, injury in this region may result in a green-stick fracture, as the cartilaginous neck is undergoing ossification. Radiograms have shown that this accident is by no means rare, and it is probably one of the most frequent causes of coxa vara.

At *school age*, injury in this region may take the form of a separation of the epiphysis of the femoral head. The correct diagnosis of this condition is extremely important, as unless proper treatment is carried out the epiphysis unites in a faulty position, and subsequent limitation of movement results. After union has occurred no manipulations can separate the fragment for the purpose of reposition in correct alignment.

This injury is usually caused by violent rotatory movements of the trunk while the body-weight is being supported on the femur. When examined the limb is found to be powerless, and there is marked eversion together with some slight shortening. The diagnosis should be confirmed by the X-rays.

Dislocations of the Hip-Joint may be (1) Congenital, (2) Traumatic, or (3) Pathological.

(1) CONGENITAL DISLOCATION of the hip-joint occurs more frequently in females than in males, and this incidence is possibly due to the fact that in the female the acetabulum looks more directly to the lateral side.

The head of the femur is situated on the dorsum ilii just lateral to the anterior inferior spine, and is enclosed within the untorn but greatly stretched articular capsule. In these cases it is doubtful whether the head of the bone has ever occupied the acetabulum, which is usually rudimentary. The capsule possesses its normal attachments, but, owing to the stretching to which it has been subjected, it resembles an hour-glass in shape. When the child begins to walk, the proximal part of the capsule has to transmit the body-weight to the femur, and the condition becomes more exaggerated. The child walks with a heavy downward lurch to the affected side, and the muscles connecting the trunk to the thigh become greatly shortened. The longer the condition is allowed to remain untreated, the more difficult will it be to carry out remedial measures and the poorer the subsequent result.

Owing to the shortening of the muscles it may be difficult to place the head of the femur in the acetabulum, but the reduction does not involve the passage of the head through a tear in the capsule, as in the case of a traumatic dislocation.

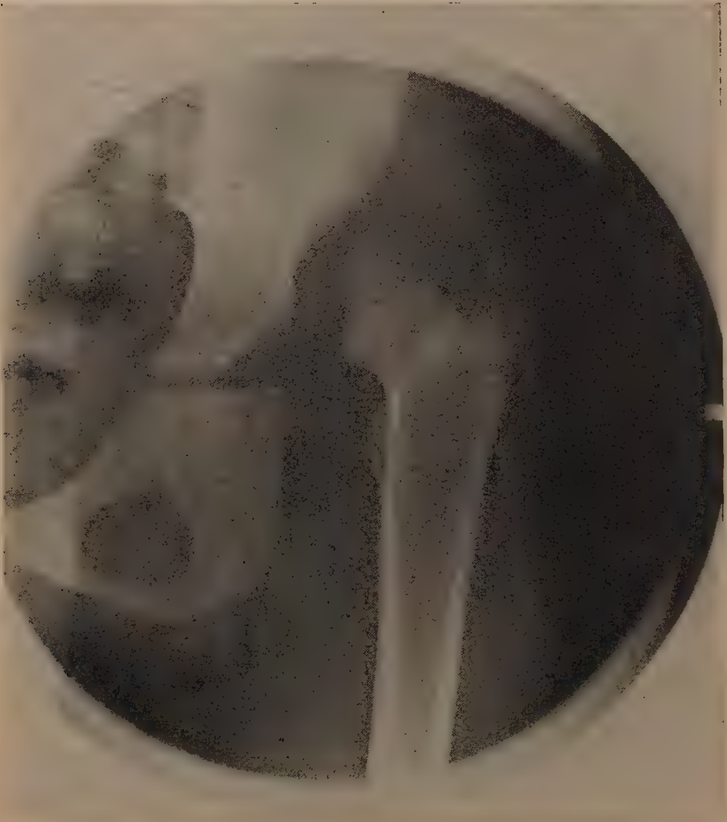

Fig. 126.—Congenital Dislocation of the Hip-Joint in a Child aged five. The head of the femur is not in the acetabulum, and the angle of the neck is greater than normal. The femur is medially rotated. Observe the epiphyses for the head of the femur and the greater trochanter. The dark area passing through the acetabulum corresponds to two of the limbs of the triradiate bar of cartilage.

Since the socket of the acetabulum may be undeveloped or rudimentary, it is a matter of great difficulty to retain the head of the femur in place after the reduction has been effected.

Further, the proximal part of the hour-glass shaped capsule becomes nipped between the two articular surfaces.

After the muscles have been thoroughly stretched, torn, or divided by tenotomy, the head is placed in the acetabulum, and the limb is fixed in plaster of Paris with the thigh abducted to a right angle and laterally rotated—the " frog " position. When this is done, the head of the femur can be felt anterior to the acetabulum, where a distinct depression existed prior to the manipulations. Subsequently, the plaster case is renewed every three months, and on each occasion the limb is slightly lowered and the amount of lateral rotation similarly decreased. At the end of fourteen to twenty months the limbs should be in a normal position and walking may be resumed.

(2) TRAUMATIC DISLOCATION of the hip is comparatively rare, owing to the fact that the arrangement of the bones renders the joint osseously strong. For the same reason, fractures are relatively much more frequent.

In " regular dislocations " the ilio-femoral ligament is not damaged or only its lateral limb is torn. When both limbs of the ilio-femoral ligament are injured, or when portions of the head of the femur or the acetabulum are fractured, the dislocation is termed " irregular."

(*a*) **Regular Dislocations.**—The tear in the capsule is usually inferior or postero-inferior, and the position which the head of the femur takes up, after passing through it, depends partly on muscular action and partly on the position of the limb relative to the pelvis at the time of the accident. If the injury is produced by a heavy weight falling on the sacrum when the subject is in a stooping attitude with the lower limbs flexed and rotated medially—the common position at the time of the accident—the head of the femur passes posteriorly on to the dorsum ilii. The rarer anterior dislocation occurs when the limbs are abducted and rotated laterally.

1. The *Sub-acetabular Dislocation* is the first stage in all varieties of regular dislocations, but the head seldom remains in this position. On leaving the lower part of the capsule the femoral head at once encounters the obturator externus, and it may pass backwards, either above or below the tendon, or it may pass forwards on to the surface of the muscle.

2. *Dorsal Dislocation.*—In the commonest form of this variety, the femoral head passes backwards *above the obturator externus* and then ascends, either tearing through or passing

in front of the obturator internus and the piriformis. It comes to rest on the dorsum ilii between the piriformis and the glutæus medius. Owing to the slope of the ilium, the articular head is directed backwards and the greater trochanter forwards, *i.e.* the limb is inverted, and it is maintained in this position by the tension of the lateral limb of the ilio-femoral ligament. In addition, the thigh is slightly flexed.

The flexion, medial rotation, shortening, and constrained attitude of the limb are characteristic, and serve to distinguish this dislocation from other injuries.

More rarely, the neck of the femur becomes caught *beneath the obturator internus*. The attitude of the limb resembles that found in the variety just described, but the flexion and rotation are more exaggerated. The head may injure the sciatic nerve, which is stretched across it in the interval between the inferior gemellus and the quadratus femoris.

The lateral limb of the ilio-femoral ligament is the important agent in maintaining medial rotation, and when it is torn the limb adopts an everted position (Bigelow).

3. *Anterior Dislocation.*—From the subacetabular stage, the head may pass forwards and medially in front of the obturator externus. The greater trochanter is directed backwards and laterally, and the limb is kept abducted, extended, and laterally rotated, the eversion being produced and maintained by the ilio-femoral ligament. This variety is sometimes referred to as the "thyroid dislocation."

The head may pass still further in an upward direction, injuring the pectineus and adductor muscles, and it subsequently comes to rest somewhere between the anterior inferior iliac spine and the pubic tubercle, constituting the *pubic*, *subspinous*, and *pectineal varieties*.

(*b*) **Irregular Dislocations** are usually caused by extreme violence and the position taken up by the head is very inconstant, but it often tends to pass downwards and backwards towards the lesser sciatic foramen; the limb is usually everted (Bigelow). When the ilio-femoral ligament is ruptured, the femoral head may pass backwards below the obturator externus tendon, which is consequently stretched across the upper aspect of the neck. The head then assumes a position in the neighbourhood of the ischial tuberosity.

In the **Reduction of a Dislocation of the Hip** the head of the bone is made to retrace its course through the tear in the capsule.

1. In the *posterior group* the limb is kept flexed and adducted by the tension of the ilio-femoral ligament, which must first be relaxed by flexing and adducting the thigh still further. As the thigh is carried upwards and medially, the head of the femur passes downwards and laterally and approaches the level of the tear in the capsule, but it is still posterior to the acetabulum. The thigh is next circumducted and laterally rotated. This movement renders the relaxed ilio-femoral ligament tense, and it may be used as the fulcrum of a lever which has the femoral shaft for its long arm and the neck for its short arm. The movement of lateral rotation levers the head forwards over the posterior margin of the acetabulum, and, by completing the circumduction and finally extending the limb, the head is made to travel medially and upwards into its socket.

2. In the *anterior group* the method followed is much the same as the foregoing, but the movements are carried out in the reverse direction. The tense ilio-femoral ligament maintains the femur in a position of extension, abduction, and lateral rotation, and it must be relaxed by flexing the abducted thigh in order to release the head from its pubic position. As the thigh is elevated, the head descends to the level of the acetabulum, and it is made to travel laterally by circumducting the fully flexed thigh in a medial direction. Finally, the limb is extended, and this movement carries the head forwards and medially into the acetabulum.

(3) PATHOLOGICAL DISLOCATIONS of the hip-joint are preceded by atrophy of the surrounding muscles from disuse and by softening of the articular capsule. Sometimes, as in advanced tubercle, the acetabular margin or the head of the femur is much eroded. In these cases the joint cavity is often distended by fluid or granulations, and the thigh is maintained in the position of semiflexion, since the capacity of the hip-joint is greatest in that attitude. When the limb is adducted, the head of the bone gradually perforates the weakened capsule, but this causes so little pain that it may escape notice until the general condition has been recovered from.

It should be pointed out that pathological dislocations of the hip-joint are always posterior, owing to the position of the limb at the time of their occurrence.

The **Surgical Approach to the Hip-Joint** is planned so as to give good exposure while doing little damage. The operation of excision yields excellent results, sometimes even in cases of advanced tuberculous disease. As a rule a posterior dislocation is present, or there may have been erosion of the neck of the femur, so that the head lies loose in the acetabulum. On this account the joint is best approached from behind—**Kocher's postero-lateral route.**

The upper half of the incision corresponds to the lower two-thirds of the line joining the posterior superior iliac spine to the greater trochanter, and is in the direction of the fibres of the glutæus maximus. In its lower half the incision is carried vertically across the greater trochanter, splitting the ilio-tibial tract. The wound is deepened through the glutæus maximus, above and below, and it opens into the bursa between the tendon of the muscle and the greater trochanter. A large angular flap, consisting of skin, fasciæ, and the glutæus maximus, can now be turned medially, and this exposes the posterior border of the glutæus medius and the piriformis. When a posterior dislocation has occurred, the head of the femur is found between these two muscles.

Since the operation is usually performed in children, the epiphysis of the greater trochanter is still partly cartilaginous, and this simplifies the next step, which consists in turning forwards the insertion of the glutæus medius. The oblique insertion of the muscle (p. 421) is removed along with its periosteum and a thin layer of cartilage, and the insertions of the obturator internus and piriformis are treated in a similar way, but they are turned backwards. When these steps have been carried out, the trochanteric fossa, the neck of the femur, the head, if present, and the remains of the dorsal aspect of the capsule are all exposed.

The capsule is then split in its long axis, and the neck of the femur is divided at its distal end and removed. The condition of the acetabulum and the synovial membrane can then be explored satisfactorily and dealt with. The greater trochanter is brought to the surface and is trimmed to fit the acetabulum. It is then implanted into the latter at an angle corresponding to that of the original neck, and, in order that this position may be maintained, an assistant keeps the limb in the required degree of abduction until the operation is completed and the special abduction splint can be applied. The remains of the capsule and the tendons which were removed are now stitched together over the trochanter, and the split glutæus maximus is sutured. A gauze drain may be passed down to the neighbourhood of the joint, but no tube is necessary, because, as the acetabulum is now occupied by the trochanter, there is no space to drain.

This operation aims at obtaining an *ankylosed* and therefore a *stable* joint, which is the first essential. When the limb has been kept in a plaster case for a year and firm bony union has occurred, the child is allowed to walk. In order to bring the limbs together, the pelvis is depressed upon the affected side when the abducted limb is placed upon the ground, and the acetabulum looks almost directly downwards like an inverted cup, thus ensuring stability. Adduction of the sound limb is necessary, and the centre of gravity, which is upset by the tilting of the pelvis, is restored by a compensatory lumbo-thoracic scoliosis. The sole of the boot on the sound limb may be thickened to make certain that the pelvis will be sufficiently tilted, and later, as the ankylosed joint grows stronger, the thickening may be gradually reduced. Finally, the sole of the boot on the affected limb may be gradually thickened, in the hope that the tilting of the pelvis will give way to a gradual angulation in the proximal part of the femoral shaft.

When excision of the hip-joint is performed in those cases in which the limb is markedly *adducted*, a preliminary tenotomy of the shortened adductors is necessary. This enables the limb to be abducted, and allows the trochanter to be placed and kept in the acetabulum. Further, as the aim is to obtain an ankylosed joint with the limb abducted, the adductors will no longer be required. A vertical incision is made along the tendon of the adductor longus, and that muscle is exposed together with the gracilis at its medial border. Both are cut across with scissors, and their ends retract, exposing the adductor brevis and the anterior division of the obturator nerve. Both these structures are divided, and the adductor magnus, with the posterior branch of the obturator nerve on its surface, is brought into view. The nerve is cut through and the greater part of the muscle is divided. The wound is then closed, and the excision is performed in the manner already described.

The **Anterior Route for Excision of the Hip-Joint** is carried out through a vertical incision, made distally from the anterior superior iliac spine, and the skin, superficial and deep fasciæ are divided. The sartorius is exposed at the medial side of the wound, running distally and medially (p. 403), while laterally the anterior margin of the tensor fasciæ latæ is found.

The wound is deepened in the V-shaped interval between these muscles, until the rectus femoris is brought into view. This muscle is retracted medially, and at this stage the ascending branch of the lateral circumflex (p. 414) may be divided. The anterior aspect of the capsule is then exposed.

This route may be adopted in tuberculous disease of the hip-joint when there is an abscess opening on the anterior aspect of the limb, provided that a posterior dislocation is not present. It may also be utilised when operative interference is necessary in congenital dislocations.

Attitude of the Lower Limb in Disease of the Hip-Joint.—Semi-flexion is the position of rest assumed in all joints. Consequently this is the position which the limb first takes up when there is effusion into the hip-joint, since in this attitude the tense ilio-femoral ligament is relaxed.

The commencement of tuberculous disease in the femoral neck, associated with a simple effusion into the joint, is sufficient to cause *flexion* and slight *lateral rotation*. When the synovial membrane is attacked the thigh becomes *abducted* in addition. As a result of the position assumed by the limb, the pelvis is tilted downwards to the affected side to enable the foot to reach the ground, and a compensatory adduction of the sound limb becomes necessary to restore the parallelism of the two limbs. Scoliosis of the lumbo-thoracic region restores the centre of gravity (p. 439). As a result there is *apparent lengthening* of the diseased limb, but the real condition is readily discovered by measurements and the examination of the relative positions of the anterior superior iliac spines.

As the disease progresses the existing flexion increases, and the pelvis becomes tilted forwards to accommodate itself to the altering conditions. To prevent the centre of gravity from being thrown too far forwards the lumbar curve is greatly exaggerated, constituting the condition of *lordosis*. At the same time the sound limb must also take up a flexed position. The intervertebral joints of the lumbo-sacral region acquire a greater degree of mobility, and passive movements carried out upon the diseased joint are transferred to them at once owing to the rigidity and spasm of the surrounding muscles. Under anæsthesia and during sleep the muscles become relaxed. In the latter case this allows some movement between the diseased articular surfaces, and the consequent irritation of the exposed nerve-endings produces the " starting pains."

In order to reduce the amount of tilting of the pelvis, compensation is sometimes gained by flexing the knee and extending the ankle on the diseased side, so that the patient walks on the balls of the toes.

The condition in which the limb is *flexed, adducted,* and *rotated medially* is commonly found in tuberculous disease, and it is often described as a later stage of the preceding condition. It seems possible, however, that in these cases adduction is present from the beginning, and that the attitude is due to a reflex stimulation of the adductor muscles by the obturator nerve, which helps to supply the joint (p. 416). With the thigh flexed and adducted, lateral rotation would result in the tightening of the ilio-femoral ligament. The limb, therefore, becomes rotated medially, and in this position the ligament is slackened to its furthest extent. As a result of the adduction of the diseased limb, the sound limb is abducted to maintain their parallelism, and the pelvis is depressed to the sound side. This necessitates a compensatory scoliosis, and the centre of gravity takes up a position over the healthy limb.

In this attitude the diseased limb *appears to be shorter* than its fellow. If measurements show that the shortening is real, then either a pathological dislocation has occurred or the femoral neck has been eroded. In both cases the upper border of the greater trochanter is found above Nelaton's line (p. 429).

When extension by weight and pulley is used to undo the deformity of flexion and abduction in tuberculous disease of the hip-joint, the force is primarily applied in the long axis of the deformed limb. As the deformity is slowly overcome the pulley is gradually lowered and carried medially. To prevent the extending force from simply increasing the downward tilt of the pelvis on the affected side, a greater weight must be applied to the sound limb. A perineal band extending to the top corner of the bed on the diseased side acts as a fulcrum over which the two weights pull, and the greater weight, being on the sound limb, tends to restore the pelvis to its normal position and, at the same time, to reduce the abduction of the affected limb.

When the deformity consists of flexion and adduction, weights only need to be applied to the affected limb, as the pelvis is tilted upwards on that side. A perineal band to the top corner of the bed on the sound side is used to provide a fulcrum, and the normal position of the pelvis is gradually restored.

Surgical Approach to the Neck of the Femur.—The region of the greater trochanter and the neck of the femur may be approached either by a vertical incision over the trochanter or by a U-shaped incision (p. 421).

The vertical incision is carried through the fascial insertion of the glutæus maximus, exposing (1) the insertion of the glutæus medius, proximally, (2) the postero-distal part of the trochanter, and (3) the tendinous origin of the vastus lateralis, in the distal part of the wound. *Plastic operations* on the neck of the femur (Jones; Murphy) and *sub-trochanteric osteotomy* may be carried out by this route. The latter operation is performed when the hip-joint is ankylosed in bad position and may consist of the removal of a wedge-shaped portion or in division of the femur. When flexion constitutes the more marked deformity, the base of the wedge is posterior, but, when adduction is more pronounced, the base is on the lateral aspect.

After the femur has been exposed by cutting through the vastus lateralis, the periosteum is divided transversely, distal to the greater trochanter, and the cut edges are elevated from the bone. A wedge of bone may then be removed from the required site and the periosteum is stitched together again. When the wound has been closed the limb is placed in the best position obtainable, and is kept fixed by the necessary splints.

The **Shaft of the Femur** is so obscured by its muscular covering that actual palpation is impossible. Thickening of the shaft may be determined by grasping the thigh firmly from in front so that the finger tips are inserted along the line of the medial (or lateral) intermuscular septum, while the thumb is inserted along the line of the lateral (or medial) intermuscular septum. In comparing the circumferential measurements of the two limbs it must be remembered that thickening of the femoral shaft may be accompanied by atrophy of the surrounding muscles, so that, although the one limb is normal and the other abnormal, the measurements obtained may be practically equal.

In *osteo-myelitis*, incisions to expose the femoral diaphysis are made along the line of the lateral intermuscular septum, as few important structures intervene between the surface and the bone in this situation. The incision splits the ilio-tibial tract and exposes the vastus lateralis. When the wound is deepened through this muscle, the vastus intermedius (crureus) is exposed and may be elevated from the lateral surface of the femur. If the incision is extended over the distal part of the diaphysis, the vastus lateralis is retracted forwards from the intermuscular septum, which is drawn backwards together with the short head of the biceps. The distal part of the lateral surface of the femur is thus exposed, and the anastomosis between the descending branch of the lateral circumflex and the lateral superior genicular artery (p. 450) may be seen on the bone.

The *distal part of this incision* may be employed in performing cuneiform osteotomy for genu varum (p. 470).

In **Operations for Genu Valgum** the distal portion of the shaft is approached from the medial side. The centre of the incision lies one finger's breadth anterior and one finger's breadth proximal to the adductor tubercle, and the wound is directed distally and forwards, parallel to the fibres of the vastus medialis. It thus lies anterior to the articular branch of the arteria genu suprema (anastomotica) and proximal to the distal epiphyseal cartilage, which corresponds in level to a horizontal line drawn through the adductor tubercle. After division of the skin and fasciæ, the vastus medialis is split and the bone is exposed. The periosteum is incised vertically for about one inch, and transverse cuts are made at each end of this incision so that two small periosteal flaps may be elevated. Cuneiform osteotomy or partial division of the femur may then be carried out.

Fractures of the Proximal Extremity of the Femur.—The neck of the femur may be fractured (1) at its proximal end, close to the head, or (2) at its distal end, close to the greater trochanter.

1. This fracture is common in elderly people and is generally due to indirect violence, but the force required is not great owing to the rarefied condition of the bone. In healthy adults the injury may result from a fall on the greater trochanter and, in this case, the neck may be impacted into the cancellous tissue of the head.

The fracture is *entirely intra-capsular* and the fragments may be completely separated or they may be retained in more or less accurate apposition by the periosteum and synovial membrane (Fig. 125). In old people non-union of the fragments is very common. It is due partly to the reduced vitality, but especially to the fact that the blood-supply to the head from the neck is damaged and the supply *via* the ligamentum teres (Fig. 125) is insufficient.

If the neck is impacted into the head the amount of shortening is usually small and special treatment is not called for. When shortening and eversion are pronounced, active measures must be taken to obtain good alignment, unless the patient is advanced in years. The older methods—Liston's splint, and extension by weights, etc.—have been replaced by that introduced by Whitman. The limb is abducted, so that the proximal fragment is forced against the anterior part of the capsule by the neck and the broken surfaces are brought into apposition. The limit of normal abduction is determined by a comparison with the sound limb, and the fractured limb is maintained in this position, and with the capsule tense, by a plaster case. When the limb is adducted after union has occurred, the head rotates upwards, and it is found that there is little or no shortening.

2. Fractures through the distal part of the neck of the femur, although occasionally caused by indirect violence, are commonly due to falls on the greater trochanter. Owing to the line of the femoral attachment of the capsule (p. 425) the fracture is *intra-capsular anteriorly but extra-capsular posteriorly*. When the injury is due to direct violence, the neck is frequently driven into the greater trochanter, where it may remain impacted, or the trochanter may be comminuted. In the latter condition there is considerable widening of the bony prominence in an antero-posterior direction, and this is more readily determined owing to the relaxation of the ilio-tibial tract.

When the fracture is not impacted there is definite shortening, and the limb is everted, partly owing to its weight and partly owing to the lateral rotator muscles, which are much stronger than the medial rotators. In impacted fractures these signs may be entirely lacking and, in addition, there may be some slight power of movement at the joint.

As this variety of fracture usually occurs in healthy adults, good bony union is generally obtained, but care must be taken to ensure a proper alignment of the limb and prevent shortening.

Fractures of the Shaft of the Femur.—When due to *indirect violence* the fracture is usually oblique or spiral, and the fragments tend to override one another. The displacement, therefore, is greater in amount than it is in fractures due to *direct violence*, where the break tends to be transverse. The degree of displacement depends on the direction of the causative force, the action of muscles, and the influence of gravity.

In **Fracture of the Proximal Third of the Shaft** the proximal fragment becomes abducted and laterally rotated by the muscles attached to the greater trochanter, and it is flexed by the ilio-psoas. The amount of flexion is increased, as the distal fragment, which is drawn proximally by the hamstrings and adductors, passes behind the proximal fragment and tilts it forwards. In addition the distal fragment becomes laterally rotated owing to the weight of the foot and the action of the adductors.

As the proximal fragment is so short and so deeply placed, it cannot be controlled easily, and the fracture is, therefore, very difficult to treat satisfactorily. The distal fragment may be brought into line with the proximal fragment by putting the limb up, flexed and abducted, on a double-inclined plane. In this position the knee is passively flexed and the hamstrings are relaxed. The application of extension by weight and pulley helps to counteract the overlapping of the fragments.

Fractures in the Middle Third of the Shaft are more easily dealt with on account of the greater length of the proximal fragment. The displacements are due to the same forces as have been described for fracture in the proximal third. Extension by weight and pulley is employed to counteract the shortening, and eversion of the limb is prevented by maintaining the foot at right angles to the bed.

When the fracture is due to indirect violence, the extremities of the fragments are sometimes sharp and pointed. They may become embedded in the muscles, and so give rise to difficulty in reduction.

In infants this fracture is best treated in the following way. A gallows is placed across the bed immediately above the child's pelvis. The thighs are flexed at right angles to the pelvis and the legs are extended by weights and extension, acting over pulleys which are fixed to the gallows. The weights used are just sufficient to counterbalance the weight of the pelvis and lower limbs, which act as the counterpoise.

In **Fractures of the Distal Third of the Shaft (Supracondylar)** the distal fragment is rotated backwards by the gastrocnemius. At the same time it is drawn proximally by the quadriceps and hamstrings, and, owing to the first displacement, it is drawn up behind the proximal fragment. A double-inclined plane is used to relax the gastrocnemius, and extension is applied to counteract the shortening, which constitutes the chief deformity. Owing to the small size of the distal fragment, the application of extension may be a matter of difficulty. A horse-shoe shaped stirrup, which is attached to the distal fragment by sharp screws, maintains satisfactory extension and has been used with success.

The **Posterior Compartment of the Thigh** contains the powerful hamstring muscles, the sciatic nerve and its two terminal branches, the tibial (int. popliteal) and the common peroneal (ext. popliteal) nerves.

The hamstring muscles all arise from the ischial tuberosity. The *Biceps*, which passes distally and laterally, possesses a second, or short head of origin, which arises from the lateral lip of the linea aspera. These two heads unite opposite the lateral epicondyle, and their common tendon, which is easily felt through the skin, extends to the head of the fibula for its insertion. The biceps flexes the knee-joint, and is capable of producing a certain amount of lateral rotation; in addition, it acts as an extensor of the hip-joint.

The *Semimembranosus* passes distally along the medial side of the posterior compartment of the thigh, and is inserted into a groove on the postero-medial aspect of the medial condyle of the tibia. The *Semitendinosus* is smaller in bulk and lies on the surface of the semimembranosus. Its tendon (p. 449) extends to the proximal part of the medial surface of the tibia, where it is inserted behind the tendons of the gracilis and sartorius, from which it is separated by a synovial bursa (p. 456). Like the biceps, both these muscles extend the hip and flex the knee, but, since they are related to the medial aspect of the latter joint, they cause a slight amount of medial rotation.

All three muscles are supplied by the sciatic nerve (L. 4, 5, S. 1, 2, and 3), but the branch to the short head of the biceps frequently arises from the common peroneal nerve (ext. popliteal).

The **Sciatic Nerve** passes distally through the posterior compartment of the thigh on the posterior surface of the adductor magnus. Proximally it is crossed by the long head of the biceps, and in the rest of its course it is overlapped by the semimembranosus. It gives off branches of supply, which enter the flexor muscles near their origin, and, together with the obturator nerve, it supplies the adductor magnus. In the middle third of the thigh, it ends by dividing into the common peroneal (L. 4, 5, S. 1 and 2) and the tibial (L. 4, 5, S. 1, 2, and 3) nerves.

The *perforating arteries* from the profunda femoris (p. 415) enter the posterior compartment of the thigh by piercing the adductor magnus close to its insertion into the linea aspera. They form a longitudinal series of anastomoses with one another. Proximally the first perforating artery takes part in the crucial anastomosis (p. 423); distally, the third and fourth perforating arteries anastomose with the proximal muscular branches of the popliteal (p. 450).

THE REGION OF THE KNEE.

Surface Landmarks.—As there is little elasticity in the ligamentum patellæ, the *patella* remains at a constant distance from the tibial tuberosity, whether the knee-joint is flexed or extended. In extension of the knee-joint, the distal part of the articular surface of the patella is in contact with the proximal part of the trochlea (Fig. 131), but, when the joint is flexed, the patella is drawn downwards by its ligament so that its articular surface is more fully in contact with the femur. When the knee is passively extended the patella may be

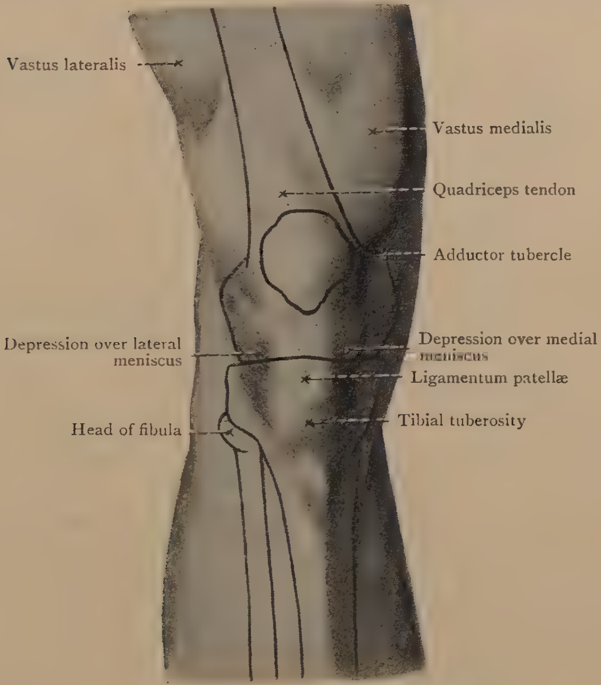
Vastus lateralis
Vastus medialis
Quadriceps tendon
Adductor tubercle
Depression over lateral meniscus
Depression over medial meniscus
Ligamentum patellæ
Tibial tuberosity
Head of fibula

FIG. 127.—Surface Landmarks in the Region of the Knee.

moved from side to side, and, owing to the elasticity of the quadriceps muscle, it may be pushed distally. When the joint is distended with fluid the articular surfaces of the patella and the femur are separated from one another. This condition is termed "floating patella," and, when the patella is gently tapped, it may be made to knock against the femur.

The *ligamentum patellæ* can be traced from the apex of the patella to the tibial tuberosity. It is about two inches long and its mid-point corresponds to the level of the knee-joint. On each side of the ligamentum patellæ a slight triangular depression can be seen when the knee is semi-flexed. The lateral depression is bounded distally by the anterior margin of the proximal extremity of the tibia, laterally by the margin of the articular surface of the femur, and medially by the ligamentum patellæ.

The medial depression is bounded by the corresponding parts of the femur, tibia, and patellar ligament. Palpation of the collateral boundaries of these depressions readily reveals the presence of lipping of the femoral condyles in rheumatoid arthritis. *Aspiration of the knee-joint* may be carried out through either of these areas, but when the joint is distended with fluid, the surface depressions are no longer visible.

The *tibial tuberosity* (tubercle) can easily be palpated ; it lies one inch distal to the line of the knee-joint. The *head of the fibula* is placed on the same level as the tibial tuberosity, but on a plane posterior to it. It serves as a guide to the common peroneal (ext. popliteal) nerve, which can be rolled against the bone as it crosses the lateral aspect of the fibular neck.

The lateral aspect of the *lateral condyle* and the medial aspect of the *medial condyle* of the femur are both subcutaneous. The *adductor tubercle* is the most proximal palpable point on the medial condyle, and when the knee is semi-flexed the *tendon of the adductor magnus* can be traced proximally from it.

In active extension of the knee-joint the tendon of the *rectus femoris* forms a tense band, 1½ inches wide, which is inserted into the proximal border of the patella. In the same position of the limb the *vastus medialis* forms a prominent elevation to the medial side of the tendon, and the *vastus lateralis* forms a similar elevation on the lateral side but it is placed at a more proximal level. A very definite depression lies immediately distal to the elevation produced by the vastus lateralis ; it is bounded medially by the rectus femoris and laterally by the *ilio-tibial tract.* The latter forms a distinct ridge, which crosses the antero-lateral aspect of the joint and can be traced distally to its attachments on the lateral condyle of the tibia and the head of the fibula.

When the knee is flexed against resistance, the tendons of the hamstrings are rendered prominent and can be palpated almost to their respective insertions. The tendon of the *semimembranosus* is felt on the medial side of the tendon of the *semitendinosus*, which, however, is more superficial. On the lateral aspect of the distal part of the thigh, the fingers can be made to sink into the popliteal fossa, through the interval which is bounded behind by the biceps tendon and in front by the ilio-tibial tract. A similar interval can be made out on the medial side behind the tendon of the adductor magnus.

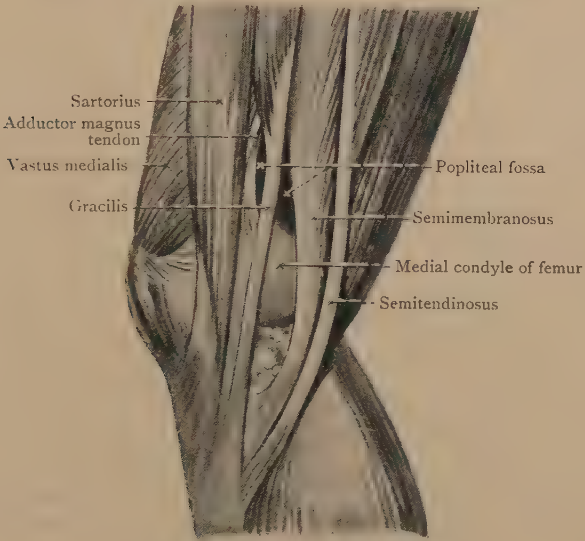
Sartorius
Adductor magnus tendon
Vastus medialis
Gracilis
Popliteal fossa
Semimembranosus
Medial condyle of femur
Semitendinosus

FIG. 128.—The Medial Side of the Knee.

The **Popliteal Fossa** lies behind the knee-joint and extends beyond it in both directions. Its *roof*, which is formed by a thin but strong sheet of deep fascia, is pierced near its centre by the small saphenous vein. Proximally, the fossa is bounded by the biceps on the lateral side, and by the semimembranosus and semitendinosus on the medial side; distally, it is bounded by the two heads of origin of the gastrocnemius. The *floor* of the fossa is formed by the popliteal surface of the femur, the posterior ligament of the knee-joint, and the posterior surface of the popliteus, which is covered by a strong layer of fascia.

The **Popliteal Artery** begins at the hiatus tendineus in the adductor magnus (p. 417), where it is continuous with the femoral artery. As it passes through the popliteal fossa it inclines laterally till it reaches the middle line of the limb, and then descends vertically to the distal border of the popliteus, where it terminates by dividing into the anterior and posterior tibial arteries. Throughout its course the artery is very deeply placed, and it lies in direct contact with the posterior ligament of the knee-joint.

Ligature of the Popliteal Artery may be carried out for aneurism, or following wounds of the vessel. The *incision* lies behind and parallel to the tendon of the adductor magnus, and when the skin is divided, the great saphenous vein and the saphenous nerve are exposed. These structures are retracted backwards together with the sartorius, which is seen when the deep fascia is incised (Fig. 128). The wound is then deepened between the adductor magnus and the semimembranosus. Flexion of the knee relaxes the latter muscle and enables it to be retracted so as to permit the finger to be inserted into the fat which intervenes between the popliteal artery and the femur. The sheath of the vessel is carefully incised on its medial aspect, and the popliteal vein and the tibial nerve, which lie on its postero-lateral side, are thus avoided.

The **Branches of the Popliteal Artery** can be divided into three groups: (*a*) muscular, (*b*) cutaneous, (*c*) articular. (*a*) The *proximal muscular* branches supply the hamstrings and anastomose with the perforating arteries (p. 415); the *distal muscular* branches are distributed to the muscles of the calf. (*b*) The *cutaneous branch* supplies the skin of the calf, and is accompanied by the medial cutaneous branch of the tibial nerve. (*c*) The *articular* branches are five in number:

1. The *middle genicular* (*azygos*) *artery* enters the knee-joint by piercing the posterior ligament, and is distributed to the structures within the capsule.

2. The *superior genicular arteries*, lateral and medial, wind round the femur, proximal to the condyles. They are in close contact with the bone, and anastomose with one another anteriorly. In addition, they anastomose with the inferior genicular arteries, and with the descending branch of the lateral circumflex and the articular branch of the arteria genu suprema (p. 418). The latter anastomosis helps to re-establish the circulation in the leg when the popliteal artery is ligatured in its proximal part.

3. The *inferior genicular arteries*, lateral and medial, wind round to the anterior aspect of the knee. In their course they pass under cover of the tibial and fibular collateral (internal and external lateral) ligaments respectively, and they anastomose with one another under cover of the ligamentum

patellæ. They communicate with the superior genicular arteries, and so take part in the important anastomosis around the knee-joint.

The **Tibial (Internal Popliteal) Nerve** (L. 4, 5, S. 1, 2, 3) arises from the sciatic in the posterior compartment of the thigh and extends distally in the middle line of the limb. In the popliteal fossa it lies superficial to the popliteal vessels and it crosses them obliquely from the lateral to the medial side. At the distal border of the popliteus the tibial nerve passes deep to the soleus and enters the posterior compartment of the leg.

As it traverses the popliteal fossa, the tibial nerve gives off (*a*) muscular, (*b*) cutaneous, and (*c*) articular branches. The *muscular branches* supply both heads of the gastrocnemius, the soleus, the plantaris, and the popliteus. The *cutaneous branch* is termed the medial cutaneous nerve of the calf (ramus communicans tibialis). It descends between the two heads of the gastrocnemius and unites with the peroneal anastomotic nerve (r. communicans fibularis) to form the nervus suralis (external saphenous) (S. 1 and 2) (p. 478). The *articular twigs*, three in number, supply the knee-joint.

The **Common Peroneal (Ext. Popliteal) Nerve** (L. 4, 5, S. 1, 2) passes distally and laterally in close relation to the medial aspect of the biceps tendon, and leaves the popliteal fossa in the interval between the tendon and the lateral head of the gastrocnemius. It then descends behind the head of the fibula and winds round the lateral aspect of the fibular neck, piercing the origin of the peronæus longus. In this situation the nerve ends by dividing into the superficial and deep peroneal nerves (musculo-cutaneous and anterior tibial) (L. 4, 5, S. 1).

The common peroneal nerve gives off no muscular branches, but it supplies *articular twigs* to the knee-joint and gives origin to the *lateral sural* nerve (L. 4, 5, S. 1), which supplies the skin over the proximal part of the tibialis anterior, and the *peroneal anastomotic nerve*, which helps to form the nervus suralis.

The **Popliteal Lymph Glands** are divided into a superficial and a deep group. The *superficial lymph glands* surround the small saphenous vein as it pierces the deep fascia. They receive afferents from the lateral aspect of the foot and leg, and their efferents open into the deep group.

The *deep lymph glands* are embedded in the fat which surrounds the popliteal vessels. They receive the efferents of the superficial group, and, in addition, most of the numerous lymph vessels from the deep tissues of the calf and the sole of the foot. The remainder of the latter pass direct to the deep subinguinal lymph glands (p. 405). The efferents of the deep popliteal lymph glands terminate in the deep subinguinal group.

Abscesses arising in these lymph glands follow some septic infection of the leg or toes. Owing to the depth at which the pus lies from the surface, its presence is difficult to determine at an early stage, but early diagnosis is necessary, as when evacuation is delayed the abscess cavity takes a long time to granulate up. This slow closure is partly due to the rigid walls of the cavity, which are formed by the hamstring tendons, and partly to the destruction of the fat in which the lymph glands are embedded.

Abscesses in the popliteal fossa are best *approached* from the lateral aspect of the knee. An incision is made behind the lateral intermuscular septum (p. 407), but in front of the biceps tendon. When the deep fascia is divided, a pair of dressing forceps can be passed medially between the biceps and the femur, and the pus is evacuated by Hilton's method in order to avoid injuring the large vessels and nerves.

The **Popliteus Muscle** arises within the capsule of the knee-joint from the lateral aspect of the lateral femoral condyle. It passes distally and medially across the joint, and is inserted into the proximal part of the posterior surface of the tibia. Near its origin the popliteus intervenes between the lateral meniscus (semilunar cartilage) and the fibular collateral ligament (p. 460). It is supplied by the tibial (int. popliteal) nerve (L. 4, 5, and S. 1) and acts as a flexor of the knee-joint. In addition, when the tibia is fixed the popliteus acts as a lateral rotator of the femur, and when the tibia is free to move it acts as a medial rotator of the tibia.

Superficial Veins of the Lower Limb.—A *venous arch* extends across the dorsum of the foot near the heads of the metatarsal bones. It is continued backwards along the medial border of the foot as the *great saphenous vein*, which ascends in front of the medial malleolus and then along the medial border of the tibia to the medial side of the knee-joint. The remainder of its course may be indicated by a line joining the adductor tubercle to the fossa ovalis (p. 406). At the latter point the great saphenous vein passes through the deep fascia and joins the femoral vein.

The *small saphenous vein* arises at the lateral extremity of the dorsal venous arch and passes backwards along the lateral border of the foot. From behind the lateral malleolus it ascends obliquely in the superficial fascia of the back of the leg, and near the centre of the popliteal fossa it pierces the fascial roof to join the popliteal vein. It usually communicates with the great saphenous by a branch which winds round the postero-medial aspect of the knee, or by one which arises at a lower level and crosses in front of the proximal part of the tibia.

Except for a short distance from their termination, both saphenous veins lie in the superficial fascia and therefore receive no muscular support. Owing to this lack of support and to the action of gravity, these veins are very liable to become *varicose*. Both veins contain numerous valves, which help to support the column of blood. The rupture of one of these valves increases the strain on the one distal to it, which in turn gives way. The unsupported vessel walls are not strong enough to support the column of blood when the patient is in the erect attitude, and they consequently become dilated and varicose. The middle third of the great saphenous vein is most frequently affected, but its proximal and distal parts and the small saphenous vein are often involved.

When the patient adopts the recumbent posture, the veins, though varicose, are able to fulfil their function, and in consequence, elastic bandages, stockings, etc., which are used as a mechanical support, should be applied before the patient rises from this posture.

Owing to the obstruction to the venous return the vitality of the skin is diminished, especially in the distal part of the limb, and chronic ulceration tends to arise after trivial injuries in this region. Healing is always tedious and may not occur unless the patient is kept in bed with the limb slightly elevated. This position assists the venous return, and so improves the vitality of the affected part.

The Bursæ around the Knee.—Numerous bursæ, some of which communicate with the interior of the joint, lie in relation to the tendons around the knee.

Anterior.—(1) The *supra-patellar bursa* almost invariably communicates with the joint. It lies behind the tendon of the quadriceps and is separated from the femoral diaphysis by an extra-synovial pad of fat (Fig. 131). It extends upwards for a hand-breadth above the proximal border of the patella, and is outlined in hydrops of the joint. Fluid may be aspirated from the knee-joint through this bursa.

(2) The *prepatellar bursa* is subcutaneous and lies in front of the distal part of the patella and the proximal part of the ligamentum patellæ. When the bursa is exposed to much pressure, effusion is apt to occur into it and the condition may become chronic, with the formation of fibrous bands and "melon-seed" bodies ("housemaid's knee"). The prepatellar bursa, when thus affected, may be removed through a semilunar incision, the base of which is distal, so that pressure on the scar is subsequently avoided.

When enlarged, this bursa projects beyond the margins of the ligamentum patellæ, and so is brought into close relationship with the capsule of the joint. In acute suppurative conditions, therefore, it is important that the bursa should be incised and drained at an early stage to prevent the joint from becoming infected. An incision is made on each side of the middle line so that the bursa may be thoroughly drained.

(3) A small subcutaneous bursa is sometimes present *in front of the tibial tuberosity* and the distal part of the ligamentum patellæ.

(4) The *infra-patellar bursa* is placed between the proximal extremity of the tibia and the deep surface of the ligamentum patellæ. It is only separated from the synovial lining of the joint by the infra-patellar pad of fat. When effusion takes place into this bursa, there is slight fulness on each side of the ligament near the tibial tuberosity, and full flexion causes pain in this region.

Postero-Lateral.—(1) A bursa is situated between the *lateral head of the gastrocnemius* and the capsule covering the lateral femoral condyle; it sometimes communicates with the cavity of the knee-joint.

(2) A small bursa is usually interposed between the *biceps tendon* and the fibular collateral (external lateral) ligament of the knee.

(3) A protrusion of the synovial lining of the knee-joint separates *the tendon of the popliteus from the lateral condyle* of the tibia. It varies in extent, sometimes forming a complete sheath for the tendon and communicating distally with the cavity of the proximal tibio-fibular joint (p. 465).

Postero-Medial.—(1) A bursa is placed between the *medial head of the gastrocnemius* and the capsule covering the medial femoral condyle. It is frequently in communication with the knee-joint.

(2) A bursa, which frequently communicates with the preceding, is situated *between the medial head of the gastrocnemius and the semimembranosus tendon.*

Gradual enlargement of these bursæ, accompanied by pain

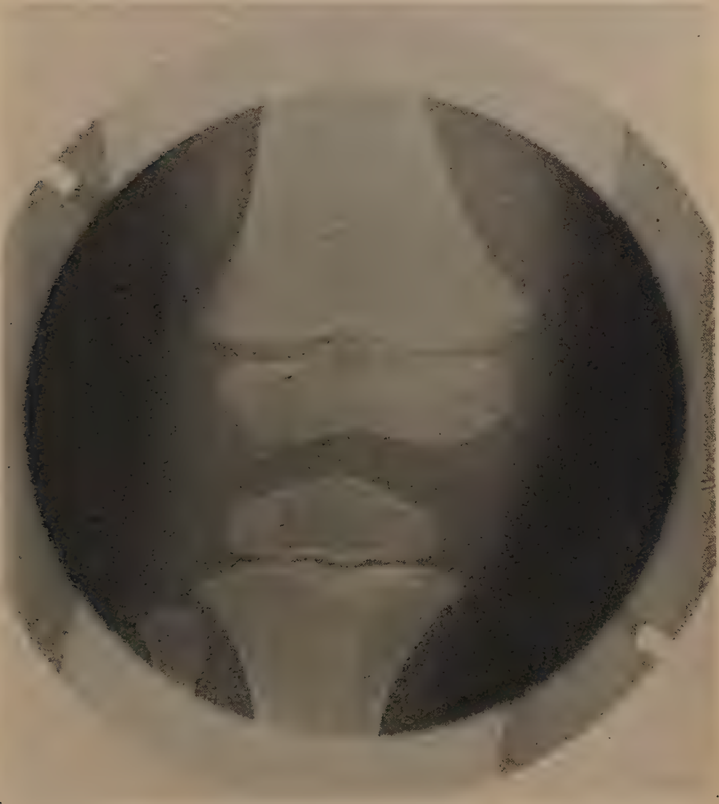

FIG. 129.—Normal Knee-Joint of a Child, aged four. Antero-posterior view. The centre of ossification for the head of the fibula is not yet present.

and limitation of movement at the knee-joint, is sometimes met with in gamekeepers and shepherds. This is said to be due to the increased amount of flexion at the knee-joint which is necessary when walking through heather and gorse. The swelling usually enlarges distally in an intermuscular interval and assumes a sausage-shape. Such swellings have been mistaken for varicose veins, and they are usually much larger than they appear to be, since they lie under the deep fascia.

(3) The tendons of the *sartorius, gracilis, and semitendinosus* are separated from one another at their insertions, and from the tibial collateral (internal lateral) ligament by one or more bursæ.

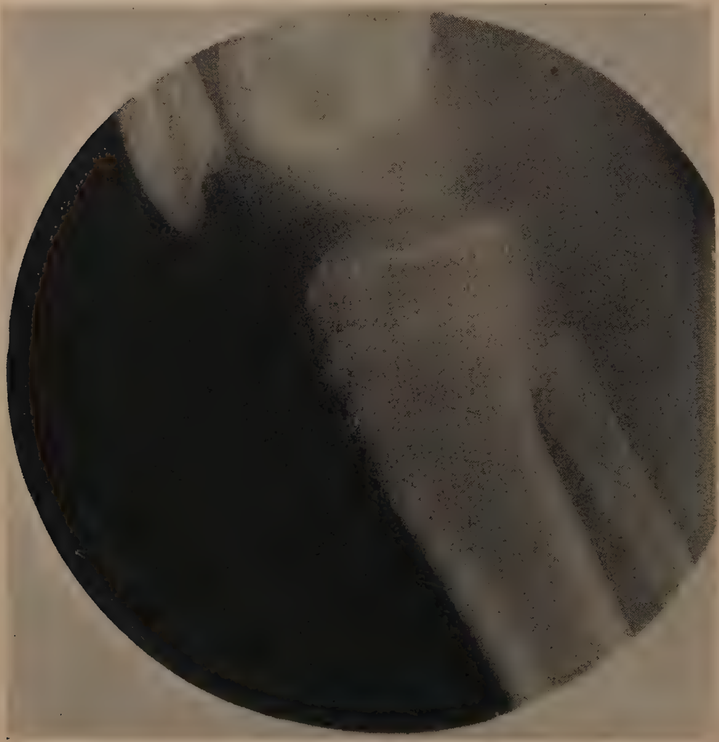

FIG. 130.—Knee-Joint of Child, aged thirteen. Lateral view. Observe the epiphyseal lines on the tibia and fibula. A separate centre of ossification is present for the tibial tuberosity. Note also the position of the head of the fibula.

Ossification of the Distal Extremity of the Femur.—A secondary centre appears in the cartilaginous distal extremity of the femur during the ninth month of fœtal life. It is the earliest secondary centre to appear, and following the general rule that epiphyses which ossify early unite late, it does not join the diaphysis till the twenty-first year. Growth in length, therefore, proceeds for a longer period at the distal than at the proximal extremity of the femur (p. 425). The distal epiphyseal line corresponds, anteriorly, to the proximal border of the articular surface, and posteriorly, to the intercondylar line. On the condyles the line is curved with a downward convexity, and on the medial side it passes through the adductor tubercle.

Ossification of the Proximal Extremity of the Tibia.—A secondary centre appears in the cartilaginous proximal extremity of the tibia shortly before birth, and the epiphysis which it forms includes both condyles and the tibial tuberosity. Occasionally the tibial tuberosity possesses a separate centre of ossification, which appears at the eleventh or twelfth year and soon fuses with the rest of the epiphysis. The proximal epiphysis of the tibia unites with the shaft at about the twenty-fourth year. The epiphyseal line usually passes through the articular surface for the head of the fibula.

The **Patella** does not begin to ossify till the third year, but ossification is complete at puberty.

The Knee-Joint.—The **Capsule** of the knee-joint is strongest on the posterior aspect of the joint, and it is quite distinct on the lateral and medial aspects. Anteriorly it forms a thin fibrous layer closely applied to the outer surface of the synovial membrane, but, proximal to the patella and over the area occupied by the patella, it is entirely deficient. On each side of the patella the capsule depends for its strength on the tendinous expansions of the vasti, lateralis and medialis (p. 414).

Proximally, the line of attachment of the capsule crosses the epiphyseal line on the lateral and medial condyles, but it remains at least half an inch distant from the margins of the articular surface. Posteriorly the capsule is attached to the proximal margins of the articular surfaces and to the intercondylar line. On this aspect, therefore, the line of attachment of the capsule practically coincides with the epiphyseal line.

Distally, the capsule is attached to the tibial condyles, a little beyond the margins of the articular surface.

The **Synovial Membrane** of the knee-joint is very extensive, and its arrangement is complicated by the presence of the intra-articular ligaments and menisci. It lines the deep aspect of the capsule, from which it is reflected on to those parts of the femur and tibia which are intra-capsular but non-articular. From the antero-distal part of the joint a triangular fold of the synovial membrane passes proximally and backwards, to be attached by its apex to the *anterior* extremity of the intercondylar fossa. This fold is termed the *patellar synovial fold* (*ligamentum mucosum*), and its free margins are known as the *alar folds* (*ligamenta alaria*). An extra-synovial but intra-capsular pad of fat lies behind the ligamentum patellæ, and the portion of it which is carried in between the two layers of the patellar synovial fold (Fig. 131) is frequently the site of hypertrophy (lipoma arborescens). In this condition grape-like pieces may become detached and constitute loose bodies within the joint. Similar hypertrophy may affect the pad of fat which intervenes between the femur and the supra-patellar bursa (Fig. 131).

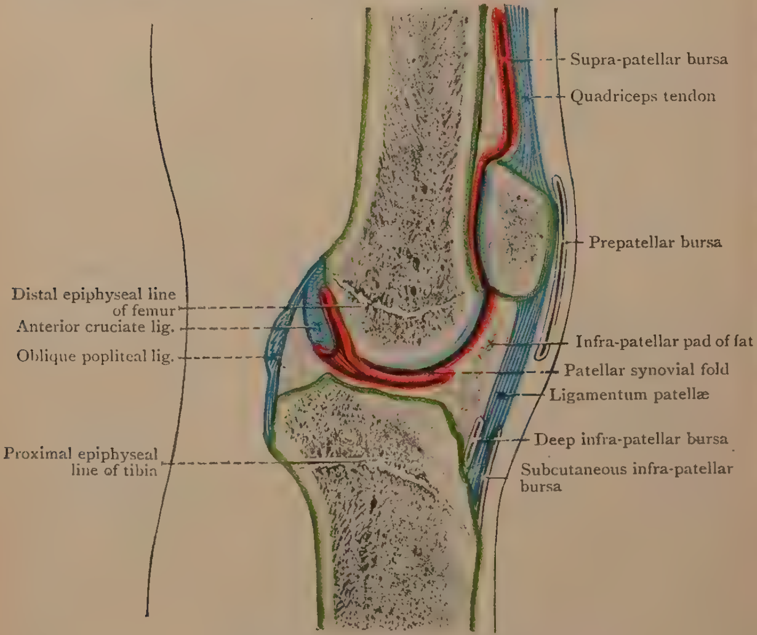
Supra-patellar bursa
Quadriceps tendon
Prepatellar bursa
Distal epiphyseal line of femur
Anterior cruciate lig.
Oblique popliteal lig.
Infra-patellar pad of fat
Patellar synovial fold
Ligamentum patellæ
Deep infra-patellar bursa
Subcutaneous infra-patellar bursa
Proximal epiphyseal line of tibia

FIG. 131.—Sagittal Section through the Knee-Joint.

Light blue = articular cartilage. Green = periosteum.
Striped blue = tendons and ligaments. Red = synovial membrane.

In the fœtus both surfaces of the menisci (semilunar cartilages) are covered by the synovial membrane, which helps to attach their peripheral margins to the tibia (coronary ligaments), but, as the result of continued pressure, they are devoid of synovial covering in the adult (Fig. 132).

In the posterior part of the joint the synovial membrane is drawn off the central part of the posterior ligament by the posterior cruciate ligament. It covers both cruciate ligaments anteriorly and on each side, so as to render them extra-synovial.

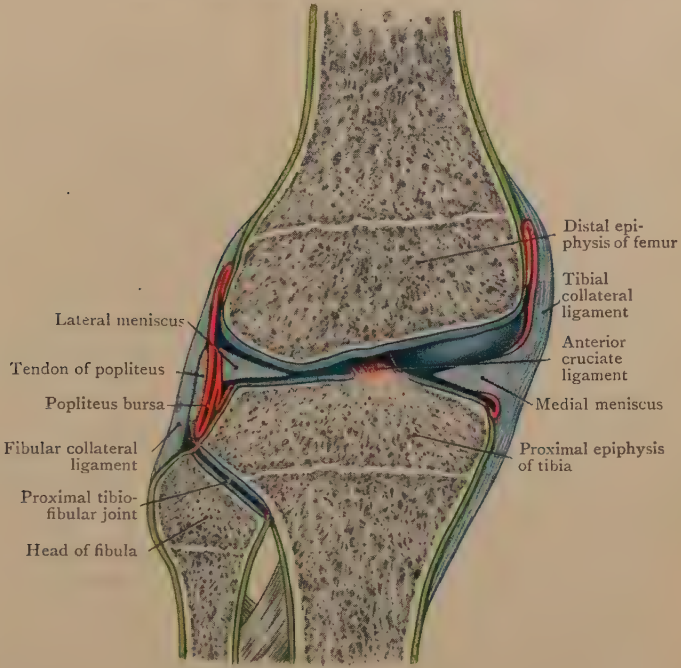
Distal epiphysis of femur
Tibial collateral ligament
Anterior cruciate ligament
Lateral meniscus
Tendon of popliteus
Popliteus bursa
Medial meniscus
Fibular collateral ligament
Proximal epiphysis of tibia
Proximal tibio-fibular joint
Head of fibula

FIG. 132.—Oblique Section through the Right Knee-Joint.
Light blue = articular cartilage. Green = periosteum.
Striped blue = ligaments and menisci. Red = synovial membrane.

Protrusions of the synovial membrane escape from the capsule to form the supra-patellar and the popliteus bursæ (p. 454).

The **Ligamentum Patellæ** (p. 448) serves to strengthen the capsule anteriorly and takes the place of an anterior ligament of the knee-joint.

The **Tibial Collateral (Internal Lateral) Ligament** is a broad flattened band which strengthens the capsule on its medial aspect. Proximally it is attached to the femur near the adductor tubercle. It crosses the medial aspect of the joint and is *firmly adherent to the peripheral border of the medial meniscus* (p. 461). Distally, the tibial collateral ligament extends to the proximal part of the shaft of the tibia, where it receives attachment behind the semitendinosus tendon.

The **Fibular Collateral (External Lateral) Ligament** forms a distinct rounded band, which is attached to the lateral condyle of the femur about half an inch from its articular margin. As it crosses the lateral aspect of the knee-joint, the ligament is *separated from the lateral meniscus by the popliteus tendon*, its associated bursa (p. 461), and the lateral inferior genicular vessels. Distally, it is attached to the head of the fibula in close relation to the insertion of the biceps.

The collateral ligaments may be strained or torn during the same violent movements of the joint which may give rise to injury of the menisci. In the former condition tenderness is experienced on palpation over the injured ligament, whereas, when the menisci are involved, the tenderness is most marked in the triangular depressions at the sides of the ligamentum patellæ (p. 448).

The **Posterior** part of the capsule is specially thickened and helps the anterior cruciate ligament to prevent hyper-extension of the joint. It is further strengthened by the *oblique popliteal ligament*, which extends obliquely across the back of the joint from the semimembranosus, at its insertion, to the medial border of the lateral femoral condyle.

The **Medial Meniscus (Int. Semilunar Cartilage)** of the knee-joint is interposed between the peripheral parts of the medial condyles of the tibia and the femur. It is semilunar in outline, and its two extremities are widely separated from one another. The narrower, anterior extremity is attached to the anterior part of the non-articular area on the top of the tibia, and in addition it is connected to the anterior part of the lateral meniscus by the *transverse ligament*. The wider, posterior extremity is attached to the posterior part of the non-articular area referred to above (Fig. 133).

The **Lateral Meniscus (External Semilunar Cartilage)** is nearly circular in outline, and its extremities are attached close to one another. Its anterior extremity is attached to the tibia immediately in front of the *intercondylar eminence* (*tibial spine*), while its posterior extremity is attached to the eminence itself, and is also connected with the posterior cruciate ligament (Fig. 133).

The menisci are thickest round their peripheral borders and thin away to their free central margins. The peripheral border of the medial meniscus is firmly adherent to the tibial collateral ligament, but the fibular collateral ligament is separated from the lateral meniscus by the popliteus tendon, its synovial bursa, and the lateral inferior genicular vessels. On this account, although both menisci are permitted a certain amount of movement to enable them to accommodate themselves to the articular surfaces in different positions of the joint, the medial meniscus is the less freely movable of the two. Further, since the extremities of the medial meniscus are more widely separated from one another than those of the lateral meniscus, the latter enjoys greater freedom.

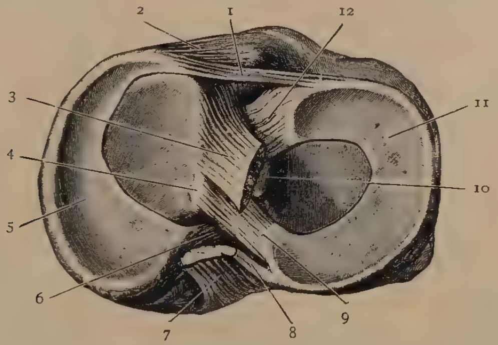

FIG. 133.—The Menisci and their Attachments.

1. Transverse ligament.
2. Anterior cornu of medial meniscus.
3. Anterior cruciate ligament.
4. Medial tubercle of intercondyloid eminence of tibia.
5. Medial meniscus.
6. Posterior cornu of medial meniscus.
7. Posterior cruciate ligament.
8. Fasciculus from lateral meniscus to posterior cruciate ligament.
9. Posterior cornu of lateral meniscus.
10. Lateral tubercle of intercondyloid eminence of tibia.
11. Lateral meniscus.
12. Anterior cornu of lateral meniscus.

Injuries of the menisci occur in forcible rotation of the flexed or semi-flexed knee. The tibia may be rotated on the femur when the latter is fixed, or the femur may be rotated on the tibia when the tibia is fixed. Statistics show that the medial meniscus suffers injury much more frequently than does the lateral meniscus, and it is probable that the comparative immunity of the lateral meniscus is due to its greater range of movement.

When the tibia is fixed and the femur is suddenly and violently rotated laterally, the lateral meniscus is able to follow the movements of the lateral condyle, and in doing so it exerts a strain on the thin concave margin of the medial meniscus through the transverse ligament. As a result a concentric splitting may occur in the anterior part of the medial meniscus, or its anterior extremity may be torn through and dragged towards the centre of the joint (Fig. 134, B).

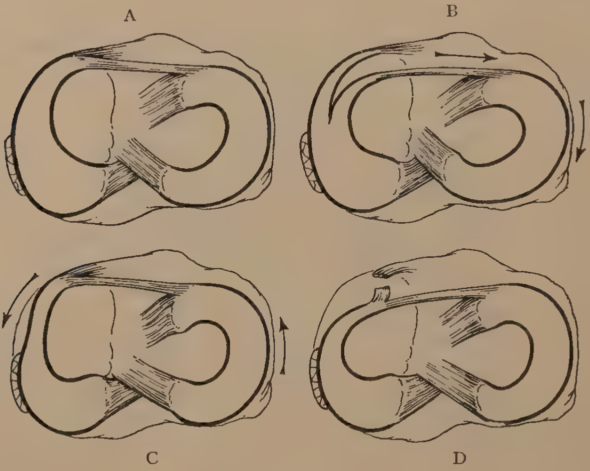

FIG. 134.—Diagram to illustrate Injuries of the Medial Meniscus.

A. Normal position of the menisci.

B. Splitting of the medial meniscus caused by traction on the transverse ligament, following violent lateral rotation of the femur on the fixed tibia.

C and D. Tearing of the anterior attachment of the medial meniscus caused by violent flexion of the knee combined with medial rotation of the femur on the fixed tibia.

In some subjects, either owing to their occupation or as the result of a constitutional disease, the capsule of the knee-joint becomes sufficiently relaxed to permit a slight amount of abduction and adduction. This constitutes a predisposing cause to injury, as, owing to the increased freedom of separation of the femur and tibia from each other, the menisci are more likely to be caught between the two articular surfaces. In extension of the knee-joint the somewhat flattened distal surface of the medial condyle of the femur is in contact with the whole of the medial meniscus. When the leg is extended, therefore, forcible medial rotation of the femur on the tibia produces little alteration in the shape of the meniscus. On the other hand, when the leg is flexed the more convex posterior surface of the femoral condyle is only in contact with the broader posterior part of the medial meniscus, and in medial rotation of the femur on the tibia the curve of this part is accentuated, while the anterior part becomes correspondingly straighter. If the violence of the rotatory movement is sufficient to tear its anterior attachment, the meniscus resumes its semilunar outline, with the result that its torn extremity projects into the centre of the joint (Fig. 134). Subsequent extension of the joint catches the meniscus between the two articular surfaces.

The **Surgical Approach** to the menisci is carried out with the knee-joint flexed (Jones) in order to obtain good exposure. The incision, which is convex forwards and extends for two inches on each side of the line of the joint, does not quite reach the margin of the patella, and a curved flap of skin and fascia is reflected backwards. A vertical incision is made in the capsule midway between the patella and the margin of the femoral condyle, and the anterior extremity of the meniscus can then be dragged forwards out of the wound. After it has been dealt with the capsule is closed and the skin margins are reunited. As the incision through the skin does not immediately overlie the incision through the capsule, leakage of the synovial fluid is hindered, while there is no subsequent weakening of the capsule in flexion and extension, such as occurs when the incision through it is made in a transverse direction.

The **Cruciate Ligaments** extend from the intercondylar fossa of the femur to the intercondylar area on the top of the tibia. They cross one another in the centre of the joint and are therefore intra-capsular, but they are excluded from the synovial cavity by the synovial membrane. The *anterior cruciate ligament* is attached to the top of the tibia in front of the intercondylar eminence, and passes upwards and backwards to reach the posterior part of the medial aspect of the lateral femoral condyle. These two bony points are farthest from one another when the knee-joint is fully extended, and in this position of the limb, therefore, the ligament is tense. Aided by the collateral ligaments and the thickened posterior part of the capsule, the anterior cruciate ligament is sufficiently strong to prevent hyperextension of the joint unless excessive force is applied. The *posterior cruciate ligament* is attached to the posterior part of the non-articular area on the top of the tibia, and extends upwards and forwards to the anterior part of the lateral aspect of the medial femoral condyle. It is relaxed in extension, but becomes tightened during flexion of the joint.

Severe strains of the knee may cause *rupture of one or both cruciate ligaments* without leading to actual dislocation of the joint. In addition to preventing hyperextension of the knee, the anterior cruciate ligament prevents the tibia from being moved bodily forwards on the femur when the joint is passively extended. If, following injury, this passive movement is obtained, the diagnosis of rupture of the anterior cruciate ligament can be made with some degree of certainty. Similarly the posterior cruciate ligament prevents the same passive movement of the tibia on the femur when the knee is flexed, and this movement can only be obtained when the ligament is ruptured.

The articular surfaces of the tibial condyles are separated from one another by a roughened non-articular area, which corresponds to the intercondylar fossa of the femur. This area, which is narrowest centrally, where it is raised up to form the *intercondylar eminence* (*tibial spine*), gives attachment to the inter-articular menisci and ligaments. Near its anterior margin it gives attachment to the anterior extremity of the medial meniscus and to the anterior cruciate ligament. The anterior extremity of the lateral meniscus is attached immediately in front of the intercondylar eminence, while its posterior extremity is attached to the eminence itself. The posterior extremity of the medial meniscus receives attachment immediately behind the eminence, and behind that lie the posterior cruciate ligament and the posterior part of the capsule (Fig. 133).

Fracture of the Intercondylar Eminence (Spine) of the Tibia is a somewhat rare injury, which has been brought to light by the use of radiography. Forcible extension of the femur upon the fixed and medially rotated tibia causes the lateral margin of the medial femoral condyle to impinge on the medial tubercle of the eminence, and so fracture it. Similarly, when the tibia is fixed in lateral rotation, forcible extension may cause the lateral condyle to fracture the lateral tubercle of the eminence (Jones).

It would appear that the injury only occurs in cases where one or other tubercle is unusually well developed. The condition causes limitation of movement, especially of extension, and if absolute rest in the extended position fails to produce a good result, or if the case is one of long standing, operative interference is advisable. The best exposure is obtained by splitting the patella vertically, the knee being kept flexed. When the two fragments are separated, the patellar synovial fold (ligamentum mucosum, p. 458) is exposed and divided, and the region of the intercondylar eminence can then be investigated. There is no necessity to wire the patella subsequently.

Spread of Tuberculous Disease in the Region of

the Knee-Joint.—*Tuberculous disease at the distal end of the femur* usually commences in the distal part of the diaphysis, and nearer to its posterior than to its anterior surface. It may spread *upwards* along the diaphysis, or it may pass *horizontally* towards the surface. In the latter case it usually spreads *backwards* and readily breaks through the thin compact bone (cortex) of the popliteal surface of the femur, giving rise to a popliteal abscess. Tuberculous disease originating in the distal part of the femoral diaphysis rarely involves the knee-joint, since in the first place, it is extra-capsular ; and in the second place, it finds less difficulty in spreading to the popliteal fossa than in passing through the epiphysis to gain the joint. If, however, the disease spreads *forwards* and breaks through the periosteum, it infects the supra-patellar bursa and then involves the joint.

When tuberculous disease originates in the proximal end of the tibial diaphysis it is entirely extra-capsular, and it commonly spreads *distally* along the shaft. It may, however, penetrate the periosteum and infect the soft parts on the *posterior* or *lateral* aspects, or cause a subcutaneous abscess on the *medial* aspect. Very rarely the disease may break through the articular cartilage and infect the proximal tibio-fibular joint. Should this joint cavity communicate with the knee-joint through the popliteus bursa (p. 454), the knee-joint itself will be secondarily infected.

When the patella is the primary site of tuberculous disease, spread to the knee-joint is likely to occur, since only the articular cartilage intervenes.

The Surgical Approach to the Knee-Joint.—The route chosen in any particular case depends partly on the area of the joint which is involved and partly on the ultimate aim of the operation. The age of the patient, too, may have some influence in determining the procedure to be adopted.

Drainage is difficult to obtain in suppurative arthritis owing to the complicated arrangement of the synovial membrane. Incisions may be made midway between the margin of the femoral condyle and the margin of the patella, on each side, in order to allow a tube to be passed across the joint. From the medial opening a director may be passed backwards across the medial surface of the medial condyle of the femur just below the attachment of the tibial collateral ligament. The point of the instrument is cut down upon when it reaches the posterior synovial pouch (p. 467). A similar proceeding can be carried out on the lateral side, and, finally, an incision should be made into the proximal part of the supra-patellar bursa. Through

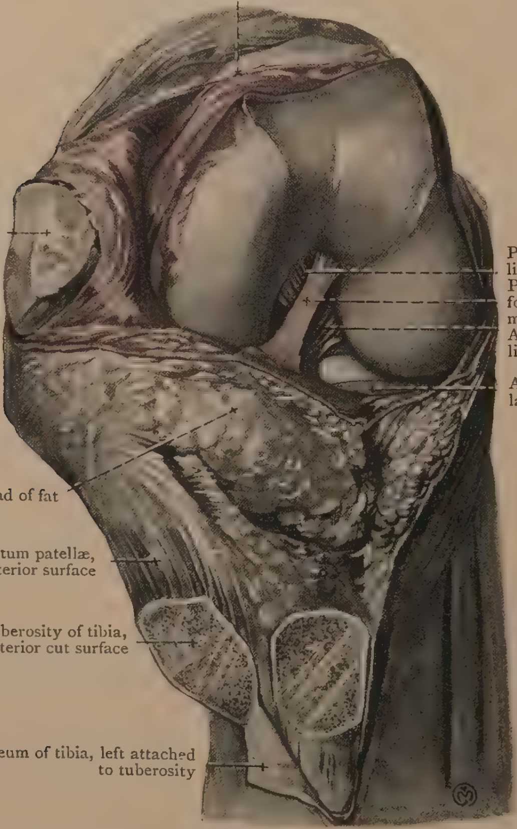
Cut edge of synovial membrane
Posterior surface of patella
Posterior cruciate ligament
Patellar synovial fold (ligamentum mucosum)
Anterior cruciate ligament
Anterior cornu of lateral meniscus
Infra-patellar pad of fat
Ligamentum patellæ, posterior surface
Tuberosity of tibia, posterior cut surface
Periosteum of tibia, left attached to tuberosity

FIG. 135.—Complete Exposure of the Knee-Joint. The dissection is described on p. 467. The synovial membrane is shown in purple.

these various incisions tubes may be arranged so as to provide adequate drainage.

In young subjects, **Inspection of the Joint** may be carried out with least damage through the lateral J-shaped incision of Kocher or through a similar incision on the medial side. The limb is slightly flexed over a sandbag, as the interior of the joint is most accessible in this position. The incision, which begins about 2½ inches proximal to the patella and a finger's breadth from its lateral margin, descends vertically over the femoral and tibial condyles and then curves gently forwards to a point about 1½ inches beyond the tibial tuberosity. When the skin and fasciæ have been elevated and retracted, the vastus lateralis and its tendinous expansion which passes to the lateral border of the patella are exposed, together with the patella and the ligamentum patellæ. The joint is then opened by deepening the vertical part of the incision. Freer access is gained by dividing the infra-patellar pad of fat and its synovial covering and by elevating the ligamentum patellæ from the tibia. In the child the ligament is freed by removing a slice of cartilage from the tibial tuberosity, but in the adult the tuberosity will require to be chipped off with a chisel. In both cases the periosteum at the distal border of the tuberosity must not be divided, since it serves to retain the tuberosity in position subsequently. Thereafter the patella, together with the quadriceps and the ligamentum patellæ, may be rotated through a right angle, and its surfaces can then be reversed by flexing the knee. The whole of the joint cavity is then exposed, and if necessary, excision of the joint can be performed (Fig. 135).

Excision of the Knee-Joint.—When it is decided before the operation that excision of the joint is necessary, a large U-shaped incision gives the best access. The transverse limb lies midway between the patella and the tibial tuberosity, and the vertical limbs ascend immediately in front of the collateral ligaments. This incision is to be recommended because it provides an anterior flap, should the condition of the joint, as revealed by the operation, call for amputation rather than excision.

The initial incision divides the skin, fascia, and the infra-patellar tendon, and opens into the cavity of the joint, which may be widely exposed by flexing the knee.

The cruciate ligaments are then removed, and this step enables the surgeon to dissect the synovial membrane from the lateral and medial parts of the posterior ligament. In this situation synovial pouches extend upwards behind the condyles, and, unless they are removed, they may give rise to subsequent recurrence of the disease.

After resection of the cruciate ligaments, it is impossible to obtain a joint which is both stable and movable, and as stability is of primary importance, osseous ankylosis should be aimed at. This result is obtained by removing the articular cartilage and a layer of bone from the condyles of the femur and tibia. When the disease has originated in the synovial membrane and the bones are not affected, the amount of bone removed should be just sufficient to ensure firm osseous union. In these cases the femur is divided just distal to the attachments of the collateral ligaments, while a slice, a quarter of an inch thick, is removed from the tibia. Owing to the obliquity of its long axis (p. 469), the femur must be divided *parallel to the line of the joint* and not at right angles to its axis, in order to maintain the limb in its normal alignment. Since the epiphyseal lines are not interfered with in either bone, the amount of permanent shortening is usually slight, and it serves to prevent the foot from dragging on the ground when the patient is able to walk again.

The articular surface of the patella and the anterior articular surface of the condyles should also be removed in order to render the resulting ankylosis more secure.

The posterior ligament of the joint is left intact when possible, as it protects the vessels in the popliteal fossa (Fig. 131). The middle genicular (azygos) artery will require to be ligatured as it enters the joint after piercing the ligament.

After the anterior flap of skin and fascia has been replaced, but before it is sutured, a long nail may be driven through each tibial condyle into the corresponding condyle of the femur. These nails should be introduced parallel to the long axis of the tibia, and care must be taken lest they penetrate the popliteal surface of the femur. This arrangement secures the bones in position until bony union occurs. Thereafter the wound is stitched up in layers.

Genu Valgum.—Under normal conditions a line drawn from the centre of the femoral head to a point midway between the two malleoli passes midway between the femoral condyles at the knee-joint. In this way the weight of the trunk is transmitted evenly to the two tibial condyles and thence to the tarsal bones.

In *rickets*, owing to irregular growth and ossification near the epiphyseal line, the medial part of the distal extremity of the femoral diaphysis may become abnormally enlarged in a downward direction. As a result, the medial part of the epiphysis is thrust distally so that the plane of the knee-joint is directed downwards, backwards and laterally instead of vertically downwards. This constitutes the condition of genu valgum. A plumb-line dropped from the femoral head passes to the lateral side of the centre of the knee-joint and to the medial side of the centre of the ankle-joint. The deformity may be so great that the angle between the long axes of the femur and tibia, which is normally about 170°, may approach

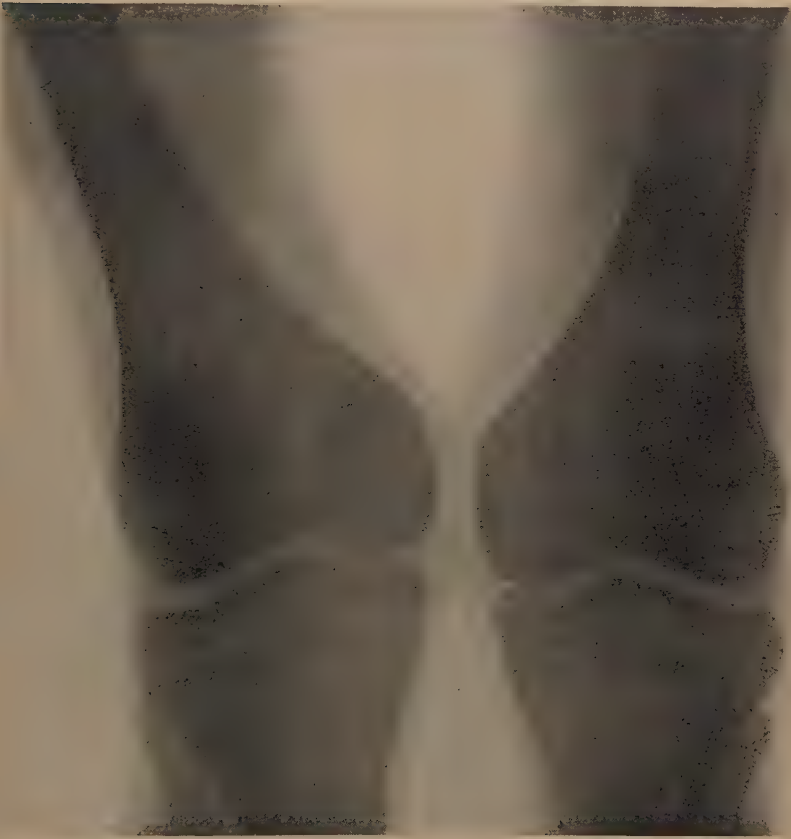

FIG. 136.—Genu Valgum. (From a Radiogram by Dr. Claude Gouldesbrough.) Observe the increased growth of the medial part of the distal end of the diaphysis of the femur.

90°. When the knee is flexed, however, the deformity disappears, as the posterior surfaces of the femoral condyles are not affected and the tibia itself has undergone no alteration. The weight of the trunk is no longer transmitted evenly to the tarsus, the pressure being now distributed over the medial border of the foot. An undue strain is therefore thrown on the plantar calcaneo-navicular ("spring") ligament (p. 489), and the condition of *flat-foot* is brought about. In some cases flat-foot is not the result but the cause of genu valgum. In the attitude of rest adopted by young adolescents who are the subjects of flat-foot, the feet are turned laterally and separated widely from one another, while the knees are slightly flexed and the thighs are adducted. When the limbs are in this position, the medial condyle of the femur is tilted up off the tibia, stretching the tibial collateral ligament. The body-weight is now transmitted through the lateral condyle of the femur, and owing to the diminished pressure on the medial part of the epiphyseal cartilage, the medial part of the distal extremity of the diaphysis undergoes abnormal growth. Thus the apparent genu valgum of the attitude of rest becomes transformed into a real genu valgum.

Certain anatomical changes are found in adults in whom the rhachitic knock-knee of childhood has been permitted to remain uncorrected. The patella may become displaced laterally so that, on flexion of the knees, it slips backwards over the lateral aspect of the joint. The biceps tendon sometimes becomes shortened and causes an appreciable amount of lateral rotation of the tibia. The disability caused by these changes may be relieved by medial cuneiform osteotomy of the femur (p. 443), combined with transplantation of the tibial tuberosity with the attached ligamentum patellæ to the medial aspect of the tibia, in exaggerated cases.

Genu Varum.—Overgrowth of the lateral part of the distal extremity of the femoral diaphysis or of the opposing part of the tibial diaphysis may occur in rickets, giving rise to the condition of "bow-knee" or genu varum. In this case the plumb-line dropped from the centre of the femoral head passes medial to the centre of the knee-joint, but lateral to the centre of the ankle-joint. As a result, the body-weight is distributed mainly over the lateral part of the foot, which is so well adapted to bear the increased strain (p. 497) that but little disability is experienced. Further, since the knees are widely separated, they do not have to avoid each other in walking, as is the case in genu valgum.

If the child is kept off its feet, the bones tend to recover their normal shape. This tendency is only apparent so long as the bones remain soft. After the age of six or seven the rhachitic softening disappears and the bones become more brittle. After this age, therefore, subcutaneous fracture or cuneiform osteotomy (p. 443) is necessary to overcome the deformity.

Injuries in the Region of the Knee.—**Supra-condylar Fracture of the Femur** (p. 445) is sometimes converted into a T-shaped fracture involving the knee-joint, by a vertical splitting of the distal fragment through the intercondylar fossa. The nature of the injury may be determined by the widening of the distal extremity of the femur and the independent movements of each condyle, and of the femoral shaft. There is usually considerable effusion into the joint, and this, together with the swelling of the surrounding parts, may mask the condition to some extent. Manipulations to restore the correct alignment are carried out with the knee flexed in order to relax the gastrocnemius, and for the same reason the limb is then placed on a double-inclined plane.

Separation of the Distal Epiphysis of the Femur usually occurs between the ages of ten and fourteen, and is due to violent hyperextension of the knee. This movement throws a severe strain on the posterior part of the capsule, which is of great strength and consequently does not give way. The strain is therefore transmitted to the femoral epiphysis and a diastasis occurs. The causative force is usually applied to the leg from behind, and on this account the epiphysis is usually displaced forwards, overriding the distal extremity of the diaphysis.

Though this injury is by no means common, it is of great importance, because it is usually complicated by injury of the popliteal vessels. The laceration is frequently so extensive that amputation may ultimately be necessary owing to the occurrence of gangrene.

Reduction is obtained by traction on the leg and downward pressure on the displaced epiphysis, the knee being flexed, and the limb is then slowly extended. If, despite these manipulations, the deformity recurs, the limb must be put up with the leg flexed.

Fracture of Either Condyle alone may be caused by violent movements of abduction or adduction. When the limb is straightened there is little displacement, but a double-inclined plane should be used in order to keep the gastrocnemius relaxed. Less severe strains of a similar nature may result in avulsion of the femoral attachment of a collateral ligament.

Fracture of the Patella may be due either to direct or to indirect violence. *In the former case,* the displacement is slight because, although the bone may be comminuted, the expansions of the vasti (lateralis and medialis) are not torn and they serve to prevent excessive separation of the fragments.

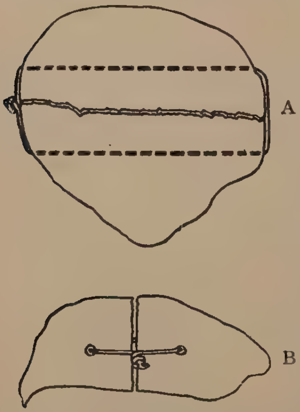

FIG. 137.—Diagram to illustrate how a Fractured Patella may be wired, without interfering with the articular surface.

A. Anterior view.
B. Lateral view.

Fractures from indirect violence are brought about when the patient, in the act of falling backwards, attempts to recover his balance by powerful contraction of the quadriceps. At the time of the accident the knee is semi-flexed and the patella is snapped across the patellar surface of the femur. Rupture of the quadriceps tendon or of the ligamentum patellæ is an alternative possibility to this fracture. The two fragments are widely separated, for, after the bone has given way, the strain tears through the expansions of the vasti tendons (lateral patellar ligaments).

When *conservative treatment* is adopted, the limb is placed on an inclined plane, with the knee extended in order to relax the quadriceps. The flexion of the hip still further relaxes the rectus femoris. Fibrous union, together with varying degrees of separation of the fragments, may be the outcome of this method of treatment, but this condition does not necessarily cause much disability.

If the fragments are to be wired, good exposure is obtained by a large U-shaped flap (p. 467). A strong silver wire is passed transversely through each fragment and the ends are twisted together at the margin of the patella. In this way the wire does not invade either the articular or the subcutaneous surface of the bone (Fig. 137).

Dislocation of the Patella may be due to violence or to exaggerated muscular action, occurring when the limb is extended and the tendinous expansions of the vasti are relaxed. The dislocation is usually over one or other condyle, but occasionally the bone is twisted round through a right angle so that its surfaces look medially and laterally. Reduction can only be effected after complete relaxation of the quadriceps.

Avulsion of the Tibial Tuberosity occurs in youth before the completion of ossification (p. 457), and is usually due to excessive muscular strain. Minor degrees of this accident cause loosening and partial separation of the tuberosity. If untreated, the condition may become chronic owing to repeated strains and want of rest, and it then gives rise to lameness and to pain and swelling locally (Schlatter's disease).

Dislocation of the Knee-Joint is a somewhat rare injury. In the least uncommon variety the tibia is displaced forwards and proximally in front of the femoral condyles. The condition results from violent hyperextension and the cruciate ligaments are torn, while the posterior ligament is either ruptured or stripped up with the periosteum on the posterior aspect of the tibia.

Reduction of this variety is obtained by downward traction on the leg and direct backward pressure on the proximal extremity of the tibia. If this method is unsuccessful, hyperextension may be added to the previous manipulations, but it may result in injuries to the large nerves in the popliteal fossa.

In posterior dislocations, which result from direct violence applied either to the front of the leg or to the back of the thigh, the proximal extremity of the tibia occupies the popliteal fossa, and may injure or compress the popliteal vessels.

Ossification of the Head of the Fibula begins about the third year and forms an epiphysis, which unites with the shaft between the ages of twenty and twenty-four. Separation of the proximal epiphysis and fractures of the head or neck of the fibula are very rare injuries, but when they do occur they are apt to involve the common peroneal (ext. popliteal) nerve (p. 451).

When *tuberculous disease* originates in the fibular diaphysis near the epiphyseal cartilage, it does not commonly spread to the proximal tibio-fibular joint, as the epiphyseal cartilage is entirely extra-capsular (Fig. 132). On the other hand, if the disease begins in the proximo-lateral part of the tibial diaphysis, the joint may be infected, as its capsule receives partial attachment to the tibial diaphysis.

THE LEG.

Surface Landmarks.—The *medial surface of the tibia* is for the most part covered only by the skin and superficial fascia, and it can therefore be examined without difficulty. On the other hand, the shaft of the fibula is clothed with muscles on all sides, and its palpation is by no means easy. The outline of the bone can best be made out along the *posterior intermuscular septum* of the leg, which corresponds to a line drawn from the posterior part of the head of the fibula to the posterior border of the lateral malleolus.

When the ankle is actively dorsi-flexed, the muscular belly of the *tibialis anterior* forms a prominent elevation on the anterior aspect of the leg, and its tendon can be traced distally and medially across the front of the ankle-joint (p. 484). The flexors of the ankle and extensors of the toes are separated from the peroneal muscles, which act as evertors of the foot, by the *anterior intermuscular septum* of the leg. This septum corresponds to a line drawn from the anterior aspect of the fibular head to the anterior margin of the lateral malleolus. In eversion of the foot the *peroneal muscles* form a surface elevation on the lateral aspect of the leg immediately behind the line of the septum. This elevation is limited posteriorly by a longitudinal furrow, which marks the position of the posterior intermuscular septum and separates the peroneal muscles from the muscles of the calf.

The lateral margin of the *soleus* is rendered prominent when the subject stands on tip-toe. It forms a narrow elevation behind the posterior intermuscular septum, and it disappears proximally under cover of the gastrocnemius.

The *common peroneal nerve* can be rolled against the bone, as it lies first behind the head and then lateral to the neck of the fibula. Its superficial position and its close relationship to the bone render the nerve liable to injury from bruising or following fractures of the fibular neck. It is occasionally divided in bullet and scythe wounds.

The Deep Fascia of the Leg.—The deep fascia is entirely absent over the medial surface of the tibia, and it forms a relatively thin sheet over the posterior aspect of the leg. It is more strongly developed over the lateral and anterior aspects, and is specially strong over the proximal part of the tibialis anterior. The anterior and the posterior intermuscular septa

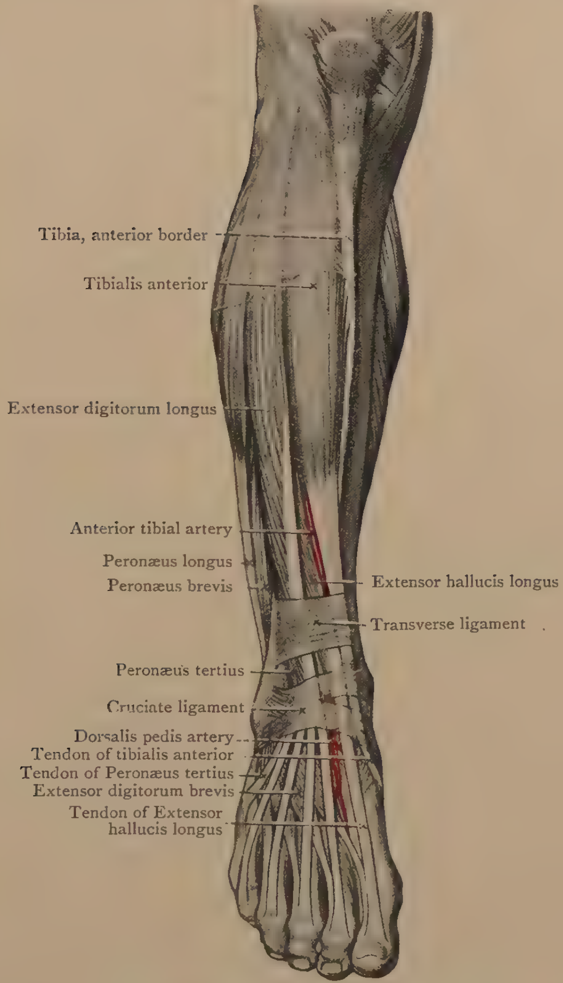
Tibia, anterior border
Tibialis anterior
Extensor digitorum longus
Anterior tibial artery
Peronæus longus
Peronæus brevis
Extensor hallucis longus
Transverse ligament
Peronæus tertius
Cruciate ligament
Dorsalis pedis artery
Tendon of tibialis anterior
Tendon of Peronæus tertius
Extensor digitorum brevis
Tendon of Extensor hallucis longus

FIG. 138.—Muscles and Tendons on the Front of the Leg and Dorsum of Foot.

attach its deep surface to the corresponding borders of the fibula. In the region of the ankle-joint the deep fascia is strengthened to form ligamentous bands which retain the various tendons in position.

The *transverse ligament* stretches between the anterior borders of the tibia and fibula immediately proximal to the malleoli. The *cruciate ligament* is made up of two bands, of which one extends from the lateral malleolus to the medial margin of the plantar fascia and the other from the medial malleolus to the upper surface of the calcaneus (p. 484). These ligaments are split by the tendons of the anterior compartment of the leg. The transverse ligament possesses two compartments, of which the medial is occupied by the tibialis anterior and the lateral by the extensor hallucis longus, the extensor digitorum longus, and the peronæus tertius. A similar arrangement exists at the cruciate ligament, with the exception that the extensor hallucis longus possesses a separate compartment, intermediate in position between the other two. As the tendons traverse the ligaments, they are surrounded by synovial sheaths, which extend for variable distances upon them.

On the medial side of the ankle-joint the deep fascia is thickened to form the *laciniate* (*internal annular*) *ligament*, which holds in place the tendons of the tibialis posterior, the flexor digitorum longus, and the flexor hallucis longus. Synovial sheaths enclose these tendons, as they lie under the ligament, and extend forwards along them into the sole of the foot.

Two similar bands are placed on the lateral side of the ankle in relation to the tendons of the peronæus longus and brevis. The *superior retinaculum* lies behind the lateral malleolus and possesses a single compartment, lined by a common synovial sheath. The *inferior retinaculum* secures the tendons to the lateral spect of the calcaneus, being attached to the bone above and below the trochlear process (peroneal tubercle) and to the process itself. It possesses two compartments separated by the process and lined by synovial sheaths which are continuous with the common sheath under the superior retinaculum. Either retinaculum may be ruptured by violent contraction of the peronæi, and the tendons are subsequently easily displaced.

Anterior Compartment of the Leg.—The *Tibialis Anterior* arises from the proximal two-thirds of the lateral surface of the tibia and the adjoining part of the interosseous membrane. Its tendon runs distally and medially, passing behind the transverse and cruciate ligaments, to be inserted into the medial side of the base of the first metatarsal and the adjoining part of the medial cuneiform. The muscle acts as a flexor of the ankle and an invertor of the foot. It is supplied by the deep peroneal (ant. tibial) nerve (L. 4, 5, and S. 1).

The *Extensor Digitorum Longus*, the *Extensor Hallucis Longus*, and the *Peronæus Tertius* arise from the fibula and occupy the lateral part of the anterior compartment. The former two are inserted into the distal phalanges; they flex the ankle-joint and extend the toes. The peronæus tertius is inserted into the dorsum of the base of the fifth metatarsal; it flexes the ankle-joint and everts the foot. All three are supplied by the deep peroneal (anterior tibial) nerve (L. 4, 5, and S. 1).

The **Anterior Tibial Artery** arises from the popliteal at the distal border of the popliteus, and at once passes forwards through the proximal part of the interosseous membrane. Its course corresponds to a line drawn from a point 1½ inches lateral to the tuberosity of the tibia to a second point, situated midway between the two malleoli. In *ligature* of the vessel, the incision is made along this line, and, after the deep fascia has been divided, the tibialis anterior is retracted medially, and the other muscles laterally. The artery is then exposed lying on the interosseous membrane with the deep peroneal nerve either on its lateral (proximal third) or anterior aspect (middle third). In the distal third of the leg the artery lies on the tibia, and is crossed obliquely by the tendon of the extensor hallucis longus. The deep peroneal nerve again lies to its lateral side.

After ligature of the anterior tibial artery, the circulation is re-established through the anastomosis around the lateral malleolus (p. 487) and the connection between the dorsalis pedis artery and the plantar arch.

The **Deep Peroneal (Anterior Tibial) Nerve** (L. 4, 5, and S. 1) arises from the common peroneal (external popliteal) on the lateral aspect of the fibular neck and descends through the anterior compartment of the leg in close relation to the anterior tibial artery. It supplies all the muscles in the anterior compartment and ends in front of the ankle-joint, by dividing into lateral and medial branches.

The *lateral branch* supplies the extensor digitorum brevis and the neighbouring articulations; the *medial branch* supplies the dorsal aspects of the adjacent borders of the first and second toes.

The **Dorsalis Pedis Artery** is the direct continuation of the anterior tibial. It commences midway between the two malleoli and runs forwards over the talus, navicular, and second cuneiform bones. At the posterior end of the first intermetatarsal space it passes downwards into the sole of the foot and joins the plantar arterial arch, thus establishing an important communication between the anterior and posterior tibial arteries. It is placed very superficially, and its pulsations can readily be felt on the lateral side of the flexor hallucis longus tendon.

When the anterior tibial is a small vessel, the dorsalis pedis may be derived from the perforating branch of the peroneal artery.

The **Superficial Peroneal (Musculo-Cutaneous) Nerve** (L. 4, 5, S. 1, 2) arises from the common peroneal nerve opposite the neck of the fibula. It passes forwards between the bone and the peronæus longus muscle, and then descends immediately behind the anterior intermuscular (peroneal) septum. In this part of its course it supplies branches to the peronæus longus and brevis muscles. At the junction of the middle and distal thirds of the anterior intermuscular septum the nerve pierces the deep fascia and then passes distally and medially across the extensor tendons. It supplies the skin on the dorsum of the foot, the medial side of the dorsal aspect of the hallux, and the adjacent sides of the second, third, fourth, and fifth toes. The adjacent sides of the first and second toes are supplied by the medial division of the *deep peroneal* (*anterior tibial*) *nerve*, while the lateral side of the fifth toe receives branches from the *nervus suralis* (p. 451).

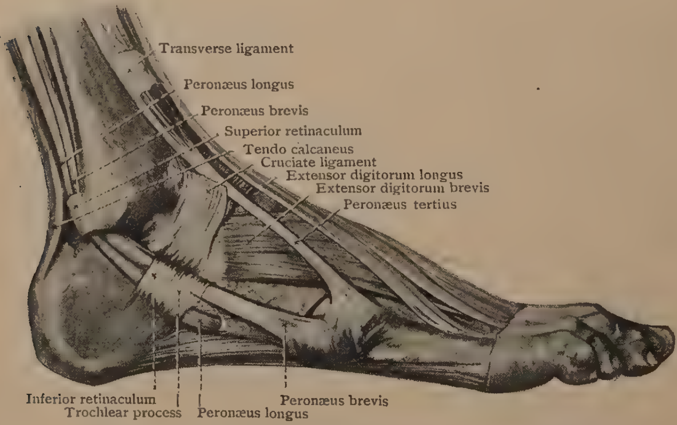
Transverse ligament
Peronæus longus
Peronæus brevis
Superior retinaculum
Tendo calcaneus
Cruciate ligament
Extensor digitorum longus
Extensor digitorum brevis
Peronæus tertius
Inferior retinaculum
Trochlear process
Peronæus longus
Peronæus brevis

FIG. 139.—The Lateral Aspect of the Ankle and Foot.

The **Lateral Compartment of the Leg** is occupied by the **Peronæus Longus** and **Brevis**, which both arise from the lateral aspect of the fibula and pass down behind the lateral malleolus. In this situation they possess a common synovial sheath and are kept in place by the superior retinaculum (p. 476). Below the lateral malleolus the tendons run forwards over the lateral aspect of the calcaneus, and the brevis passes above and the longus below the trochlear process. In this situation the peronæi are retained in place by the inferior retinaculum (p. 476), and each possesses a synovial sheath, which is continuous proximally with the common sheath.

The brevis is inserted into the dorsal aspect of the tuberosity of the fifth metatarsal, and its synovial sheath reaches almost to the insertion. The longus enters the groove on the plantar surface of the cuboid and crosses the sole of the foot obliquely to be inserted into the lateral side of the base of the first metatarsal and the adjoining part of the medial cuneiform (Fig. 147). In the foot the peronæus longus is very deeply placed, and it is surrounded by a synovial sheath which may or may not be continuous with the sheath which encloses it on the lateral aspect of the ankle.

Both muscles act as plantar flexors and evertors of the foot, and they are supplied by the superficial peroneal (musculocutaneous) nerve (L. 4, 5, and S. 1).

The tendon sheaths of the peronæi are sometimes the site of tuberculous disease, and it is important that the condition should be recognised at an early stage. Otherwise the disease may spread along the sheath of the longus into the sole of the foot and infect the tarsal joints. Good exposure is obtained by a lateral J-shaped incision from behind the lateral malleolus to the base of the fifth metatarsal. To ensure the complete removal of the disease, the retinacula must be divided and their synovial lining dissected away. Thereafter the retinacula should be reunited over the replaced tendons.

The Posterior Compartment of the Leg.—The muscles of the posterior compartment consist of a superficial and a deep group. The superficial group comprises the gastrocnemius, the plantaris, and the soleus, while the deep group comprises the flexor hallucis longus, the tibialis posterior, and the flexor digitorum longus.

The **Gastrocnemius** arises from the distal part of the femur by two heads of origin, which are inserted into a common tendon, half-way down the leg.

The **Soleus**, which lies under cover of the preceding muscle, arises from the proximal part of the posterior surface of the fibula and by a linear origin from the popliteal line and the medial border of the tibia. These two muscles together constitute the **Triceps Suræ**, and their tendons unite to form the *tendo calcaneus* (*Achillis*), which is inserted into the middle part of the posterior surface of the calcaneus. A small bursa is interposed between the tendon and the upper part of the posterior surface of the bone. It sometimes becomes inflamed after excessive walking, and it may be affected in gout or gonorrhœal rheumatism.

The **Plantaris**, which arises close to the lateral head of the gastrocnemius. has a short muscular belly ending in a long, thin tendon, which is inserted into the calcaneus on the medial side of the tendo calcaneus.

These three muscles receive their nerve-supply from the tibial (internal popliteal) nerve (L. 4, 5, S. 1 and 2), and they act as plantar flexors of the ankle-joint. In addition, the gastrocnemius and plantaris assist in flexing the knee-joint.

Both the tendo calcaneus and the plantaris tendon may be *ruptured* by violent muscular efforts ; in the case of the former the tendon is exposed by a longitudinal incision, and the torn ends are sutured together. Occasionally, instead of rupturing, the tendo calcaneus tears off a fragment from the postero-superior part of the calcaneus—fracture by avulsion (Fig. 146). In this case the incision lies along the lateral border of the tendon and curves forwards along the lateral surface of the calcaneus. In order to approximate the fragments it may be necessary to lengthen the tendon, and this may be effected by a series of hemi-divisions along each border. The fragment is then screwed into place and the foot is put up in a plaster case, with the knee flexed and the toes pointed so as to relax the gastrocnemius and the soleus as far as possible.

The **Deep Group of Muscles** is separated from the superficial group by a strong layer of the deep fascia, which extends from the posterior border of the fibula to the medial border of the tibia.

The **Tibialis Posterior** arises from the posterior surface of the interosseous membrane and the adjoining parts of the tibia and fibula. Its tendon passes distally and medially, and, as it grooves the medial malleolus, passes through a separate compartment of the laciniate ligament. It is mainly inserted into the navicular tuberosity ; but, in addition, it sends strong slips to all the other tarsal bones and to the bases of the middle three metatarsals. These slips strengthen the plantar ligaments of the foot and assist in maintaining the longitudinal and transverse arches (p. 497).

The **Flexor Digitorum Longus** arises from the posterior surface of the tibia, medial to the tibialis posterior. It inclines slightly laterally as it descends, and, where it passes through the laciniate ligament, it lies lateral to the tibialis posterior tendon.

The **Flexor Hallucis Longus** arises from the posterior surface of the fibula, lateral to the tibialis posterior. Opposite the ankle-joint it passes through a separate compartment of the laciniate ligament, being separated from the flexor digitorum longus tendon by the tibial nerve and the posterior tibial vessels.

All three muscles are supplied by the tibial nerve (L. 5, S. 1 and 2). They act as plantar flexors of the ankle-joint, but, in addition, the tibialis posterior inverts the foot, while the other two flex the toes

The **Posterior Tibial Artery** arises from the popliteal at the distal border of the popliteus and descends between the deep muscles and the fascia which covers them. It may be mapped out on the surface of the limb by a line drawn from the middle of the popliteal fossa to the mid-point between the tendo calcaneus and the medial malleolus. The commencement of the artery is on the same level as the tibial tuberosity. At first it lies on the tibialis posterior, but near the ankle-joint it is placed on the tibia between the flexor hallucis longus and the flexor digitorum longus tendons. It terminates under cover of the laciniate ligament by dividing into the lateral and medial plantar arteries.

Ligature of the posterior tibial artery is usually carried out from the medial side, in order to avoid injuring the superficial group of muscles. The incision is made a finger's breadth behind the medial border of the tibia in its proximal third, and retraction of the skin and fasciæ exposes the free border of the medial head of the gastrocnemius, which overlaps the origin of the soleus from the medial border of the tibia (p. 480). The wound is deepened through the soleus, exposing the strong fascia which covers the deep muscles. After this fascia has been carefully split, its lateral part is raised from the underlying muscles, and the posterior tibial artery with its venæ comites is exposed, lying on the tibialis posterior. In the proximal third of the leg the tibial nerve lies close to the medial side of the artery, and must be avoided when the ligature is applied.

The **Tibial Nerve** passes distally through the posterior compartment in close relation to the posterior tibial vessels. At first it lies on their medial side, but as it descends it crosses them superficially and lies on their lateral side at the ankle. It gives off branches of supply to the deep muscles (p. 480) and terminates under the laciniate ligament by dividing into the lateral and medial plantar nerves.

The **Peroneal Artery** arises from the posterior tibial soon after its commencement and runs distally in association with the flexor hallucis longus. It lies to the lateral side of the posterior tibial artery and, just proximal to the ankle-joint, gives off a perforating branch which pierces the interosseous membrane and descends in front of the lateral malleolus.

The **Surgical Approach to the Tibia**, whether for exploration or for resection, is carried out along the *medial surface* of the bone. The incision is vertical and is carried down to the periosteum, care being taken to avoid injuring the saphenous nerve and the great saphenous vein as they lie in front of the medial malleolus. Resection of the whole diaphysis, or of a portion of it, may be carried out in the manner already described in the case of the humerus (p. 39). Along the interosseous crest and near the epiphyseal cartilages the periosteum is more adherent than it is elsewhere, and it is consequently more liable to injury in these areas. When the epiphyseal cartilage is affected and it is feared that shortening of the tibia will result, subsequent inversion of the foot may be obviated by fracturing the fibula and allowing the ends to overlap.

In the **Surgical Approach to the Fibula** the incisions are planned to avoid injuring the superficial peroneal (musculocutaneous) nerve. Subperiosteal resection of the proximal or middle thirds is carried out through an incision along the line of the posterior intermuscular septum. *In the proximal third* the wound is deepened between the adjoining borders of the soleus and the peronæus longus, and care must be taken not to injure the common peroneal nerve as it winds round the fibular neck.

In the middle third, the incision exposes the peronæus longus in front and the flexor hallucis longus behind, the latter muscle projecting from under cover of the lateral border of the soleus.

In the distal third, the incision lies just posterior to the anterior intermuscular septum, and the periosteum is divided between the peronæus brevis and the peronæus tertius.

Fractures of the Leg may involve one or both bones. When only one bone is fractured there is little displacement, and the sound bone acts as a satisfactory support.

Both bones may be fractured as the result of *direct* or *indirect violence*. In the former case the fractures are transverse and occur at the same level in both bones. In indirect violence the bones give way at different levels, the tibia at the junction of its middle and distal thirds, and the fibula at the junction of its middle and proximal thirds. When displacement occurs, it is due to the powerful triceps suræ, which draws the distal fragments upwards behind the proximal fragments and often causes some degree of anterior angulation.

As the medial surface of the tibia is covered only by skin and superficial fascia, fractures of this bone are not uncommonly compound.

THE REGION OF THE ANKLE AND FOOT.

Surface Landmarks.—The two malleoli serve as important guides to the surgeon in operations in the region of the ankle-joint. The *lateral malleolus* is the larger of the two, and its tip lies a quarter of an inch distal and three-quarters of an inch posterior to the tip of the *medial malleolus*. The *trochlear process* (*peroneal tubercle*) of the calcaneus can usually be felt one finger's breadth below the lateral malleolus, but it is sometimes too small to be identified. When the foot is actively everted the tendons of the *peronæi*, *brevis* and *longus*, can be made out as they pass respectively above and below the trochlear process.

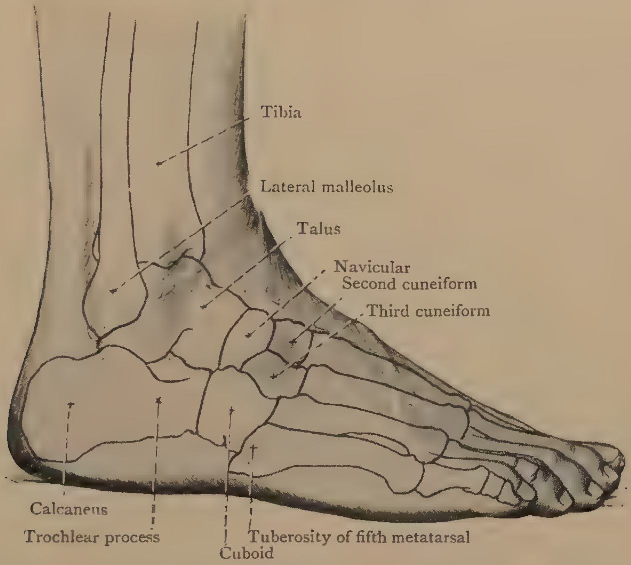
Tibia
Lateral malleolus
Talus
Navicular
Second cuneiform
Third cuneiform
Calcaneus
Trochlear process
Tuberosity of fifth metatarsal
Cuboid

FIG. 140.—The Bony Landmarks on the Lateral Aspect of the Ankle and Foot.

In active extension of the toes the *extensor digitorum brevis* produces an elevation on the lateral part of the dorsal aspect of the foot, and, when the muscle is relaxed, pseudo-fluctuation can be obtained by palpating it transversely. The posterior part of the muscle overlies the *calcaneo-cuboid joint* (p. 489), and behind the joint the anterior part of the upper surface of the *calcaneus* can readily be distinguished.

The *tuberosity on the base of the fifth metatarsal*, which lies three fingers' breadths in front of the lateral malleolus, forms a prominent landmark on the lateral border of the foot. It should be remembered that the tuberosity projects in a backward direction, and that, on this account, in disarticulations (Hey's and Lisfranc's) at the tarso-metatarsal joint the knife, entered on the lateral side, must be carried forwards and medially.

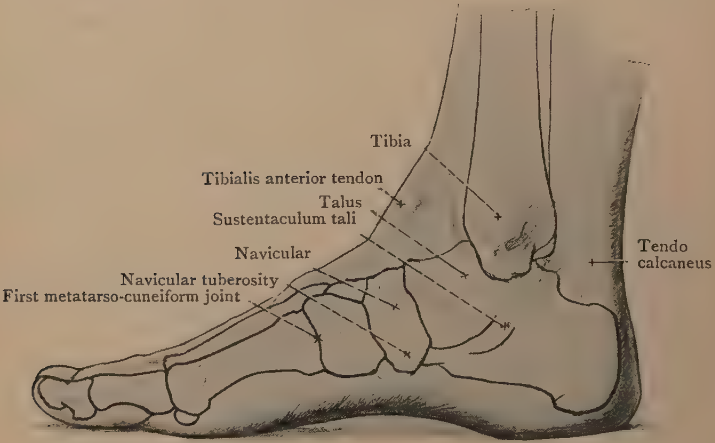

FIG. 141.—The Surface Landmarks on the Medial Side of the Ankle and Foot.

When the ankle is actively flexed with the toes extended (dorsi-flexed), the tendons of the *extensor longus digitorum* and *hallucis* are rendered very prominent, as the skin and superficial fascia on the dorsum of the foot are thin and the deep fascia is not specially thickened except in certain situations. When the flexed foot is actively inverted, the tendon of the *tibialis anterior* can be traced downwards across the medial part of the anterior surface of the ankle-joint to its insertion into the first metatarsal and the adjoining cuneiform bone (p. 474) on the medial side of the foot.

The *sustentaculum tali* lies one finger's breadth below the medial malleolus, and it is slightly obscured by the flexor digitorum longus tendon, which crosses its medial aspect. The tendon of the flexor hallucis longus grooves the plantar surface of the sustentaculum. The *tuberosity of the navicular* lies rather more than one inch in front of the sustentaculum tali, and the interval between the two is occupied by the head of the talus (astragalus). This interval is increased in flat-foot by the downward displacement of the head of the talus, which may sometimes form a visible prominence, but it is correspondingly diminished in talipes varus (p. 500). The prominent ridge on the *base of the first metatarsal* can be felt at a point 1½ inches in front of the navicular tuberosity.

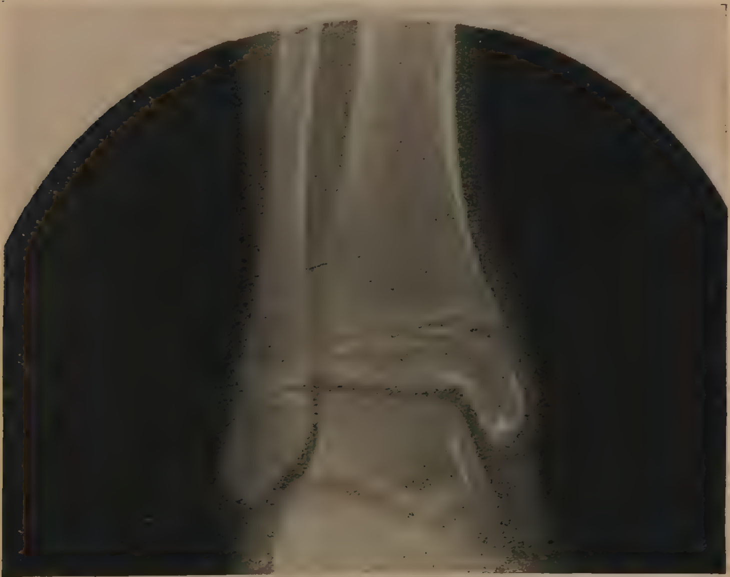

FIG. 142.—Normal Ankle-Joint of Child, aged fourteen. Antero-posterior view. Observe the levels of the epiphyseal lines of the tibia and fibula.

The *first metatarso-phalangeal joint* lies a little in front of the centre of the ball of the great toe, while the others are placed one inch behind the web of the toes.

The *level of the ankle-joint* can be made out when the foot is passively flexed and extended alternately, as the anterior border of the distal extremity of the tibia is easily felt. When the foot is extended, the anterior part of the upper surface of the *body of the talus* projects beyond the tibia and can be examined immediately distal to it. The *head of the talus* can be felt three-quarters of an inch above and behind the navicular tuberosity.

In effusions into the ankle-joint the extensor tendons are elevated by the distended capsule, and the depressions on each side of the *tendo calcaneus* (*Achillis*) become occluded.

Ossification of the Distal Extremities of the Bones of the Leg.—Secondary centres appear in the cartilaginous distal extremities of the tibia and fibula about the second year, and the epiphyses so formed unite with the diaphysis during the nineteenth year.

As the fibula projects distally beyond the tibia, the epiphyseal lines of the two bones are situated at different levels so that the distal extremity of the fibular diaphysis is in relation to the tibial epiphysis (Fig. 142), and therefore to the joint-cavity—when present (p. 487)—of the distal tibio-fibular articulation. The fibular diaphysis is sometimes intra-capsular in relation to the ankle-joint.

The Ankle-Joint.—At this joint the talus articulates with the tibia by its superior surface and with the malleoli on each side. The necessary stability is obtained by the downward projection of the malleoli, which descend on each side of the talus and only permit a slight degree of lateral movement. The upper surface of the talus is wider in front than it is behind, and on this account, side to side movements at the ankle-joint occur more freely when the foot is extended than when it is flexed.

The **Capsule** of the ankle is relatively weak. *Proximally*, it is attached to the fibular and tibial epiphyses around the margins of their articular surfaces. *Distally*, it is attached around the articular surface of the talus except on the anterior aspect of the joint, where it extends on to the neck of the bone (Fig. 144), which is thus in part intra-capsular.

The *synovial membrane* lines the interior of the capsule, and anteriorly it is reflected over the intra-capsular part of the neck of the talus.

The *anterior* and *posterior ligaments* of the ankle are special thickenings of the capsule which require no detailed description.

The **Deltoid Ligament** strengthens the medial part of the capsule. It is narrow at its proximal attachment to the medial malleolus, but widens out distally and is attached not only to the talus but also to the sustentaculum tali, the plantar calcaneonavicular ("spring") ligament and the navicular bone.

The **Lateral Ligament** consists of three separate bands. (1) The *anterior talofibular ligament* stretches from the anterior border of the lateral malleolus to the lateral side of the body of the talus. (2) The *calcaneo-fibular ligament* is a cord-like band which extends from the tip of the malleolus to the lateral surface of the calcaneus. (3) The *posterior talofibular ligament* passes transversely from a depression on the medial aspect of the lateral malleolus to the posterior process (tubercle) of the talus (Fig. 143).

The **Distal Tibio-Fibular Joint** is usually a syndesmosis and permits of practically no movement. The two bones are connected by a strong *interrosseous ligament* and by the *inferior transverse ligament,* which extends from the depression on the posterior part of the medial surface of the lateral malleolus to the posterior border of the distal extremity of the tibia. Occasionally, however, there is a joint-cavity, which communicates freely with the cavity of the ankle-joint.

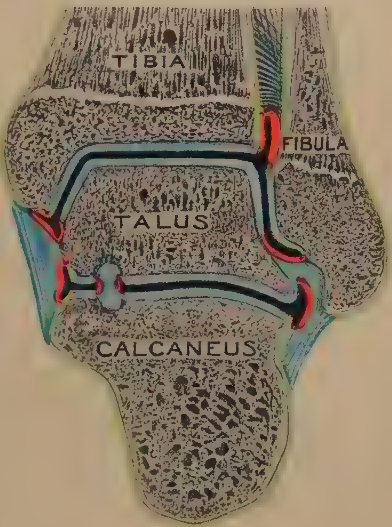

FIG. 202.—Frontal Section through the Ankle Joint, the Tibio-Fibular Syndesmosis, and the Talo-Calcaneal Joints. The deltoid ligament, on the medial side, and the posterior talo-fibular and the calcaneo-fibular ligaments, on the lateral side, are shown in the section. The strong interosseous talo-calcanean ligament is seen forming the lateral boundary of the joint between the head of the talus and the sustentaculum tali. The positions of the distal epiphyseal lines of the tibia and fibula should be observed.

Light blue = articular cartilage.
Striped blue = ligaments.
Green = periosteum.
Red = synovial membrane.

Anastomosis round the Ankle.—An important anastomosis occurs in the region of the ankle-joint. Around the lateral malleolus the *terminal* and *perforating branches* of the *peroneal* anastomose with the *lateral malleolar* branch of the anterior tibial and the *lateral tarsal* branch of the dorsalis pedis. On the medial side of the ankle the *medial malleolar* branch of the anterior tibial anastomoses with the *medial calcanean* branches of the lateral plantar artery.

Spread of Tuberculous Disease in the Ankle Region.—When tuberculous disease originates in the *distal end of the diaphysis of the tibia*, it is entirely extra-capsular and extra-synovial (Fig. 143), and, on this account, the ankle-joint is rarely involved. The disease commonly spreads along the diaphysis, producing diffuse osteo-myelitis, or it may spread towards the surface of the bone, perforate the periosteum, and affect the soft parts.

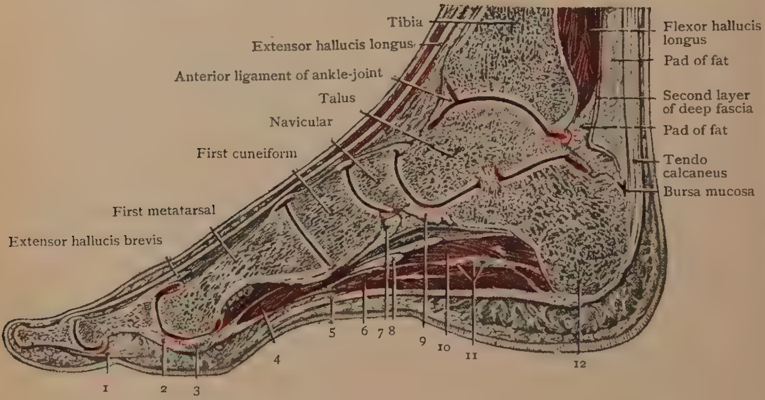
Tibia
Extensor hallucis longus
Anterior ligament of ankle-joint
Talus
Navicular
First cuneiform
First metatarsal
Extensor hallucis brevis
Flexor hallucis longus
Pad of fat
Second layer of deep fascia
Pad of fat
Tendo calcaneus
Bursa mucosa
1
2
3
4
5
6
7
8
9
10
11
12

FIG. 144.—Sagittal Section of Foot, showing some of the Articulations. The synovial membranes are shown in red.

1. Flexor hallucis longus.
2. Plantar accessory metatarso-phalangeal ligament.
3. Sesamoid bone.
4. Flexor hallucis brevis.
5. Plantar aponeurosis.
6. Flexor digitorum brevis.
7. Tibialis posterior tendon.
8. Flexor digitorum longus tendon.
9. Plantar calcaneo-navicular ligament.
10. Quadratus plantæ.
11. Lateral plantar vessels and nerve.
12. Calcaneus.

Tuberculous disease originating in the *distal end of the fibular diaphysis* spreads in a precisely similar manner, but the ankle-joint may be infected when the fibular diaphysis is intra-capsular (p. 486).

When the disease commences in the *neck of the talus*, it may spread (1) *upwards*, when it at once involves the synovial membrane of the ankle-joint; (2) *backwards*, so as to infect the body of the bone, whence it spreads through the articular cartilage, either upwards to the ankle-joint or downwards to the talo-calcanean joint; (3) *forwards*, so as to infect the talo-calcaneo-navicular joint (Fig. 144).

The Joints of the Foot.—The **Talo-Calcanean Joint** lies immediately below the ankle-joint and possesses a separate synovial membrane. At this joint the inferior surface of the body of the talus articulates with the upper surface of the calcaneus (Fig. 144).

The **Talo-Calcaneo-Navicular Joint** is formed by the head of the talus, the posterior surface of the navicular and the upper surface of the sustentaculum tali. This large joint-cavity, which is lined by a single synovial membrane, is closed infero-medially by the *plantar calcaneo-navicular ligament*, and is shut off from the talo-calcanean joint by the strong *interosseous talo-calcanean ligament.*

The *plantar calcaneo-navicular* (" *spring* ") *ligament* stretches from the anterior border of the sustentaculum tali to the plantar surface of the navicular. It is of great strength so as to enable it to support the head of the talus and the part of the body-weight which it transmits.

The **Calcaneo-Cuboid Joint** lies midway between the lateral malleolus and the base of the fifth metatarsal. It is provided with a separate synovial membrane and is supported inferiorly by the *short* and *long plantar ligaments.*

In Chopart's amputation at the " transverse tarsal " joint, the talo-navicular and calcaneo-cuboid joints are cut through. On the medial side, the knife is inserted behind the navicular tuberosity and is carried forwards and laterally, following the convexity of the head of the talus. On the lateral side the knife is inserted midway between the lateral malleolus and the base of the fifth metatarsal, and is carried backwards and medially, following the line of the calcaneo-cuboid joint. This operation does not secure a good bearing surface, as the talus, which is no longer supported by the plantar calcaneo-navicular ligament, is tilted forwards by the weight of the trunk and the calcaneus is correspondingly tilted upwards posteriorly, despite division of the tendo calcaneus.

The *joint between the medial cuneiform and the first metatarsal* possesses a separate joint cavity, but the remaining inter-tarsal, tarso-metatarsal, and inter-metatarsal joints are frequently lined by the prolongations of a single synovial membrane.

In the *amputations of Hey and Lisfranc*, the foot is disarticulated at the tarso-metatarsal articulation. The line of the articulation passes medially and slightly forwards across the foot from the lateral side. When the knife is inserted behind the tuberosity of the fifth metatarsal, it must be carried forwards for a short distance before the joint cavity is opened, and it can then be carried medially and slightly forwards in the line of the joints until the second metatarsal is encountered. The base of the second metatarsal projects backwards between the medial and lateral cuneiforms, and consequently the line of its articulation with the second cuneiform is posterior to the other tarso-metatarsal joints. The knife is then inserted on the medial side of the foot just behind the base of the first metatarsal, and is carried laterally and slightly backwards through the first joint until it is again obstructed by the base of the second metatarsal. After division of the dorsal cuneo-metatarsal ligaments, an attempt is made to flex the metatarsus on the tarsus. This process puts on the stretch the *strong interosseous ligaments* which connect the base of the second metatarsal to the medial and lateral cuneiforms, and after they have been divided by cutting backwards, the disarticulation may be completed by cutting through the plantar cuneo-metatarsal ligaments. Instead of disarticulation, the base of the second metatarsal may be sawn across; or the medial cuneiform may be sawn through on a level with the second cuneo-metatarsal joint, and the base of the second metatarsal can then be disarticulated by division of the strong interosseous ligament which connects it to the lateral cuneiform bone.

The intertarsal or tarso-metatarsal joints may be infected with tuberculous disease from a focus in one of the tarsal or metatarsal bones, as the disease requires to erode only the articular cartilage.

Injuries in the Region of the Ankle-Joint.—Injuries in this region commonly follow falls or twists in which the weight of the body is transmitted along a line which is either lateral or medial to the usual axis (p. 468). As a result the foot is over-inverted or over-everted, and a slight degree of adduction or abduction may be present. The precise nature of the injury will depend on the position into which the foot is forced by the violence, but it must be remembered that, in children, a diastasis may occur instead of a fracture. These injuries almost always involve the ankle-joint, and the consequent swelling tends to obscure the subcutaneous bony points.

Sprains of the Ankle usually occur following over-inversion of the foot. The anterior talo-fibular and sometimes the calcaneo-fibular ligaments (anterior and middle fasciculi of the external lateral ligament) are torn, and in severe cases the anterior part of the capsule also is ruptured. Tenderness is experienced on palpation over the attachments of these ligaments (p. 487) but no pain is elicited on examination of the subcutaneous surface of the fibula. Swelling and discoloration are often more marked than they are when a fracture is present.

A somewhat similar condition results from over-eversion of the foot, but in this case tenderness is experienced over the attachments of the deltoid ligament (p. 486).

Pott's Fracture.—Fracture of the distal part of the fibula is a common accident, as the region is frequently subjected to violence, and the ligaments of the tibio-fibular syndesmosis (p. 487) are stronger than the bone. The term "Pott's Fracture" includes two distinct varieties of injury: (*a*) fracture of the distal part of the fibula together with injury of the deltoid ligament or medial malleolus, and (*b*) fractures of the distal extremity of the tibia, together with tearing of the lateral ligament of the ankle or fracture of the lateral malleolus.

(*a*) In violent eversion of the foot, the deltoid (internal lateral) ligament is overstretched and may either give way or tear off the medial malleolus. In children, a diastasis of the tibial epiphysis may result. If the violence continues to act the lower part of the lateral surface of the talus is forced against the lateral malleolus and the distal part of the fibular shaft gives way, unless the powerful ligaments of the distal tibio-fibular joint are torn through. The latter condition does occasionally occur, and is indicated by a great increase in the width of the ankle. In these circumstances the talus may be dislocated upwards between the tibia and fibula (Dupuytren's fracture).

(*b*) In violent inversion of the foot, the upper part of the lateral surface of the talus is tilted laterally and downwards against the lateral malleolus and the lateral ligament gives way, or the fibula fractures proximal to the tibio-fibular joint. Continuance of the violence forces the medial surface of the talus upwards and medially against the medial malleolus, which gives way, often breaking off an irregular fragment from the distal extremity of the tibia.

Fractures in this region may be associated with incomplete dislocations of the foot.

Dislocation of the Talus is rare and is often compound.

When deformities in this region are being corrected, the knee should be passively flexed to relax the tension of the muscles of the calf. Subsequently the foot should be kept at right angles, for in this position the widest part of the talus occupies the interval between the two malleoli, and contracture of the tendo calcaneus is unlikely to occur. It is wiser to err on the side of inversion rather than eversion, as in the latter case flat-foot may subsequently develop, and to avoid this sequela, care must be exercised to see that the medial margin of the hallux, the medial malleolus and the medial border of the patella are all in the same straight line.

Surgical Approach to the Ankle - Joint. — In arthrotomy, arthrodesis, excision of the joint or removal of the talus, the best approach is obtained by means of *Kocher's lateral J-shaped incision*, with or without some slight modification. This incision begins behind the fibula and extends below the lateral malleolus to the trochlear process (peroneal tubercle), being placed above the nervus suralis and the small saphenous vein. From this point it curves gently forwards to end a little behind the insertion of the peronæus tertius (p. 477). The flap thus outlined, which consists of skin, fascia and periosteum of the lateral malleolus, is dissected forwards off the peronæi and the malleolus, while below, after division of the cruciate ligament, it is dissected off the anterior talo-fibular ligament (p. 487), the anterior ligament of the ankle and the extensor digitorum brevis. The whole flap is then retracted to the medial side together with the extensor tendons. After the retinacula have been split and the peroneal tendons divided, the three parts of the lateral ligament of the ankle (p. 487), and the weak anterior and posterior ligaments are cut through and the foot is forcibly dislocated by over-inversion. During this process the medial malleolus may break, but this accident is unimportant, as the deltoid ligament remains intact and the surfaces can subsequently be re-opposed.

By this method, a complete view of the interior of the joint is obtained, and the diseased synovial membrane can be entirely removed along with the anterior and posterior ligaments, but care must be taken not to injure the anterior or posterior tibial arteries as they lie in relation to the joint (pp. 477 and 481).

Excision of the Talus.—If the arthrotomy shows that the disease originated in the talus, this bone may be excised completely. The posterior part of the extensor digitorum brevis is elevated, and the talo-navicular joint is opened. The head of the talus can be drawn upwards, and when the talo-calcanean interosseous ligament is cut through, the bone is held only by the attachment of the deltoid ligament to its medial surface (p. 486). The removal of the talus opens both the talo-calcanean and the talo-calcaneo-navicular joint-cavities, and if the synovial membrane which lines them is infected, it must be removed.

After excision of the talus, the sustentaculum tali may be removed, and the calcaneus may be further trimmed till it can be fitted in between the malleoli. When this is carried out, the lateral malleolus projects too far, and therefore requires to be shortened.

Before the wound is finally closed, the peroneal tendons are sutured, and the retinacula are stitched over them again.

Arthrodesis of the Ankle-Joint is rarely followed by completely satisfactory results, because the necessary removal of the articular cartilage decreases the size of the talus while increasing the size of the cavity into which it is to be received. This disadvantage may be minimised by inserting a large nail in an upward direction through the calcaneus and talus into the tibia, the foot meanwhile being maintained at right angles; when the nail is removed at the end of three weeks, the limb is put up in a plaster case.

The Calcaneus (Os Calcis).—Tuberculous disease may not infrequently originate in the body of the calcaneus close to the epiphyseal line, and may spread (1) *upwards and forwards*, to penetrate the articular cartilage and infect the talo-calcanean joint; (2) *medially*, through the periosteum to infect the synovial sheaths of the tendons of the tibialis posterior, etc. (p. 480); (3) *laterally*, through the periosteum, to infect the peroneal tendon sheaths (p. 479). Early recognition by radiograms is important in order that these complications may be prevented.

The *surgical approach to the calcaneus* is obtained by means of a lateral or a medial flap operation. The incision lies below the level of the tendons and the flap includes all the soft parts and the periosteum. In the child, since the body of the bone is not completely ossified, a thin layer of its cartilaginous surface is elevated with the periosteum. The focus may then be gouged out and the flap replaced.

In more advanced cases, where freer access is desired, the incision begins behind the tuberosity of the fifth metatarsal and, passing backwards round the heel below the tendo calcaneus, ends on the medial aspect slightly in front of the medial malleolus. A large flap, consisting of soft parts, periosteum, and cartilage, can then be turned down from the lateral, posterior, and medial aspects of the calcaneus.

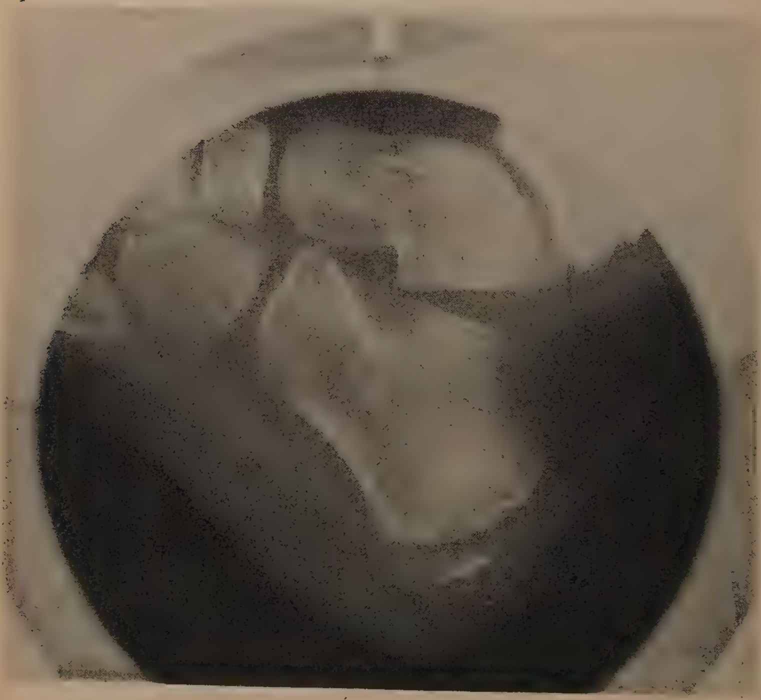

FIG. 145.—Normal Ankle-joint. Lateral View. Observe the calcanean epiphysis.

Ossification of the Tarsus.—At birth, ossific centres are present in the calcaneus, the talus and the cuboid. The lateral cuneiform begins to ossify during the first year, the middle cuneiform during the second year, and the medial cuneiform and the navicular during the third or fourth year. A secondary centre appears in the cartilaginous posterior extremity of the calcaneus during the eighth year, and forms an epiphysis which unites with the body of the bone between the ages of sixteen and twenty. A separate centre for the posterior process (external tubercle) of the talus is sometimes present, and it may remain separate, being then known as the *os trigonum* (Fig. 146).

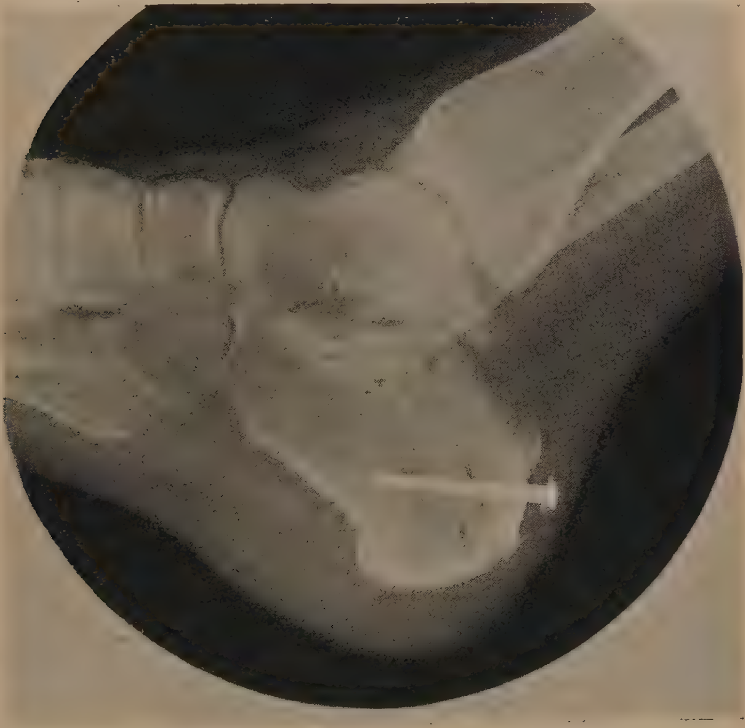

FIG. 146.—Avulsion Fracture of the Calcaneus. The fragment has been fixed in position with a screw. Note the increased density of the shadow caused by the superimposed lateral malleolus. It partially obscures the *os trigonum tarsi*, which is present in this case.

Fractures of the tarsal bones may occur when the patient, after falling from a height, lands upon his feet. They commonly involve either the talus or the calcaneus.

The *neck of the talus* may be fractured transversely, or the body of the bone may be crushed between the calcaneus and the tibia. The condition is always accompanied by considerable limitation of movement at the ankle-joint.

Fracture of the calcaneus, which is the commonest fracture of the tarsus, is usually comminuted and is often bilateral. If there is little comminution, the fracture may be overlooked, unless X-rays are employed, as the collateral ligaments of the ankle and the tendons in relation to the calcaneus retain the fragments in fair position. It is important that the injury should be recognised, since flat-foot may result unless proper treatment is carried out. When the fragments have been moulded into position, the foot is put up at right angles and slightly inverted.

Fracture of the sustentaculum tali and avulsion of the postero-superior part of the calcaneus are rare injuries (Fig. 146).

In the examination of radiograms of the tarsus, the presence of the calcanean epiphysis and the occasional os trigonum (p. 495) must be borne in mind.

Fractures of the metatarsals are difficult to recognise as the œdema may be considerable, and there is little or no displacement, owing to the way in which the bones are bound together in the transverse arch of the foot. The prominent base of the fifth metatarsal may be fractured when the patient falls heavily on the inverted foot (Jones).

The **Deep Fascia** of the sole of the foot is termed the *plantar aponeurosis.* Like the palmar aponeurosis (p. 82), it consists of a strong central and two weak collateral parts. The central portion is attached posteriorly to the calcanean tuberosity, and anteriorly it divides into five slips, which are connected to the fibrous flexor sheaths of the toes (cf. palm of hand, p. 83). It is the central portion of the plantar aponeurosis which normally helps to support the longitudinal arch of the foot, and it is much shortened in *pes cavus* and in some of the varieties of talipes.

The weak, medial part of the plantar aponeurosis covers the abductor hallucis, which extends from the calcanean tuberosity to the medial side of the base of the first phalanx of the hallux.

Owing to the density of the central part of the plantar aponeurosis, swelling first becomes apparent on the dorsum of the foot in inflammatory conditions of the sole or of the articulations (cf. palm of hand, p. 82).

The small muscles of the sole of the foot are of less importance than the corresponding muscles in the palm of the hand, as the foot is primarily required to be a stable support for the body weight, and the movements of the individual toes, therefore, are of less consequence.

The *medial plantar nerve* (L. 4, 5, and S. 1) arises from the tibial nerve under cover of the laciniate ligament (p. 476), and runs forwards with the medial plantar artery. It corresponds to the median nerve in the palm of the hand, and, though it supplies few muscles, it supplies a large cutaneous area, including the plantar aspects of the medial three toes and the tibial side of the fourth toe.

The *lateral plantar nerve* (S. 1 and 2) corresponds to the ulnar nerve in the palm of the hand (p. 85). It arises from the tibial nerve under cover of the laciniate ligament, and accompanies the lateral plantar artery and the plantar arch. It supplies most of the muscles of the sole, the skin of the lateral part of the sole, and the plantar aspects of the fifth toe and the fibular side of the fourth toe.

At the distal border of the laciniate ligament the posterior tibial artery divides into the *lateral* and *medial plantar arteries*. The medial plantar, which is usually a small vessel, passes forwards between the abductor hallucis and the flexor digitorum brevis, and its terminal branches join the digital arteries.

The lateral plantar artery runs forwards and laterally towards the base of the fifth metatarsal, where it bends sharply medially, and becomes the plantar arch. The arch lies on the bases of the middle three metatarsals, and is completed at the posterior end of the first inter-metatarsal space, where it is joined by the dorsalis pedis artery.

Gangrene of the Foot.—When senile gangrene is due to gradual obliteration of the small arteries of the foot, it begins at the periphery and spreads in a proximal direction. The pathological process tends to be delayed, and may even come to a sudden stop, on the distal side of the large joints. The position of these lines of demarcation is determined by the anastomoses, which occur round the ankle (p. 487), the knee (p. 450), and the hip (pp. 421 and 423).

On the other hand, when gangrene is due to obstruction of one of the main arterial trunks by an embolus, its onset is sudden and a large area is rapidly involved.

The **Architecture of the Foot** is so planned that the weight of the body may be equally distributed over the bearing surface. Under normal conditions the foot forms a tripod, the points of which are the calcaneus and the heads of the first and fifth metatarsal bones. To a much lesser extent, the heads of the middle three metatarsals and the lateral border of the foot help to support the body-weight. This arrangement is maintained by the presence of *two intersecting arches*, of which one is longitudinal and the other transverse. Each is supported by ligaments, muscles and tendons, which render it somewhat elastic. On this account the arches flatten out slightly when the weight of the body is borne upon the feet and contract again as soon as the weight is removed.

The **Longitudinal Arch** is constituted by the medial border of the foot, and its keystone is formed by the head of the talus. The short posterior limb of the arch is formed by the calcaneus, while the navicular, cuneiforms, and medial three metatarsals constitute the longer anterior limb. The head of the talus is supported by the plantar calcaneo-navicular ("spring") ligament, which extends between the sustentaculum tali and the navicular (Fig. 144). This ligament is supported, in its turn, by the strong tendons of the tibialis posterior, the flexor digitorum longus and the flexor hallucis longus, which are related to its medial border and plantar aspect. The two flexor tendons cross one another in the region of the plantar calcaneo-navicular ligament and the tendinous sling which they form renders additional support. Further the longitudinal arch is strengthened by the plantar aponeurosis and the abductor hallucis, which connect the bases of its two limbs (Fig. 144).

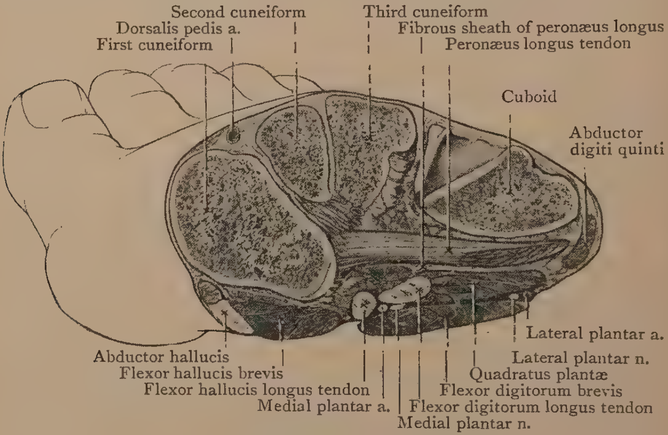
Second cuneiform
Dorsalis pedis a.
First cuneiform
Third cuneiform
Fibrous sheath of peronæus longus
Peronæus longus tendon
Cuboid
Abductor digiti quinti
Lateral plantar a.
Lateral plantar n.
Quadratus plantæ
Flexor digitorum brevis
Flexor digitorum longus tendon
Medial plantar n.
Abductor hallucis
Flexor hallucis brevis
Flexor hallucis longus tendon
Medial plantar a.

FIG. 147.—Transverse Section through the Foot, to show the Transverse Arch of the Foot and the Peronæus Longus Tendon.

The principal **Transverse Arch** is placed at the level of the distal row of the tarsus and the bases of the metatarsal bones. It is maintained by the plantar inter-tarsal and tarso-metatarsal ligaments, while the tendon of the peronæus longus stretches across the arch like a bow-string and serves to approximate its extremities (Fig. 147). Additional support is obtained from the tendinous sling formed by the crossing of the flexor longus digitorum and hallucis tendons, and from the additional slips of insertion of the tibialis posterior (p. 480), which tend to contract the arch.

Flat-Foot.—Loss of tone in the muscles which support the arches of the foot throws an increased strain upon the supporting ligaments and constitutes the first stage in the development of flat-foot. At this period treatment must be directed to the weakened muscles, or the ligaments will gradually stretch, giving rise to pain and aching over their attachments. In the second stage both arches give way, the longitudinal flattening being the more noticeable. The head of the talus sinks downwards, forwards and medially so as to increase the interval between the navicular tuberosity and the sustentaculum tali; and produces a prominence on the medial border of the foot in front of the medial malleolus. The downward displacement of the talus is accompanied by lateral deviation of the foot, and the body-weight is carried on the collapsed longitudinal arch.

Deformities of the Foot.—Talipes may be either a congenital or an acquired deformity and may affect one or both feet. In **Congenital Talipes** the foot develops in the faulty attitude and the bones are therefore modified in shape, while some of the soft structures are lengthened and others are shortened. In **Acquired Talipes,** which usually results from acute anterior poliomyelitis and occasionally from cerebral palsy or nerve injuries, the attitude of the foot depends on the over-action of some muscle or muscles following paresis or paralysis and atrophy of its antagonists.

Four primary deformities are recognised: (1) **Talipes Equinus,** in which the heel is raised and the toes are pointed; (2) **Talipes Calcaneus,** in which the foot is dorsi-flexed and the long axis of the calcaneus becomes nearly vertical; (3) **Talipes Varus,** in which the foot is inverted; (4) **Talipes Valgus,** in which the foot is everted. Combinations of these primary deformities may occur, including Talipes Equino-varus—by far the commonest of all the varieties of talipes—Equino-valgus, Calcaneo-varus and Calcaneo-valgus.

(1) **Talipes Equinus.**—When the condition is *congenital,* the muscles of the posterior compartment of the leg and the plantar aponeurosis are shortened secondarily to the faulty position. When the condition is *acquired,* it is caused by the tonus of the muscles of the posterior compartment, which are unopposed owing to paralysis or paresis of the muscles of the anterior compartment of the leg. All the anterior muscles are not necessarily involved and one or more of them may escape.

(2) **Talipes Calcaneus.**—When the condition is *congenital,* the tendons of the muscles of the anterior compartment of the

leg are shortened, while the muscles of the posterior compartment are overstretched. When the condition is *acquired*, it is caused by the tonus of the muscles of the anterior compartment, which are unopposed owing to paralysis of the posterior muscles. As in the other varieties of acquired talipes, the degree of the deformity depends on the extent of the paralysis, the condition being most marked when both the superficial and the deep muscles are affected.

(3) **Talipes Varus.**—When the condition is *congenital*, the tendons of the tibialis anterior and posterior are shortened, and the distal part of the tibial diaphysis is twisted slightly in a medial direction. When the condition is *acquired*, it results from the tonus of the tibialis anterior following paralysis of the peronæus longus or brevis, or of both these muscles.

(4) **Talipes Valgus.**—In the *congenital* variety the peronæi, longus, brevis, and tertius, are shortened while the two tibiales are overstretched. The *acquired* variety is due to paralysis of both the tibialis anterior and the tibialis posterior.

In the combined varieties, the muscles of more than one compartment are involved. Thus, in acquired talipes equino-varus, the peronæi are affected together with one or more muscles of the anterior compartment. The highest degree of the deformity is produced when all the muscles of both compartments are paralysed.

In congenital talipes, the *treatment* should be based on the degree of the deformity. In minor deformities, methodical manipulations, which tend to overcorrect the faulty position, and possibly the use of a light splint, may be sufficient. When the deformity is more pronounced, the manipulations must be more vigorous, and tenotomy of the shortened structures may be necessary before the foot can be wrenched into better position. In the worst cases operative interference, such as excision of the talus or the removal of a wedge-shaped portion from the tarsus (cuneiform tarsectomy), alone will produce correct alignment.

Cuneiform Tarsectomy.—The position of the wedge of bone removed in cuneiform tarsectomy depends on the nature of the deformity. In *talipes equino-varus*, the base of the wedge is on the lateral border of the foot. The incision, which divides the nervus suralis and the small saphenous vein, is carried backwards and laterally from the prominent head of the talus to the calcaneus. The skin and fasciæ are undercut, and this step exposes the medially displaced extensor tendons at the medial extremity of the wound and the extensor digitorum brevis at the lateral extremity. The lateral part of the cruciate ligament (p. 476) is divided and turned medially, together with the extensor digitorum brevis, which is elevated from the calcaneus. The extensor tendons are retracted, and a sharp gouge is thrust horizontally through the lateral surface of the calcaneus into the talo-navicular joint. The gouge is next inserted at the cubo-metatarsal joint and carried medially through the cuneiform bones to the medial border of the foot. Thereafter the wedge is removed, and if sufficient bone has been resected, the two portions of the foot can be brought together without any stretching of soft parts.

In order to correct the "in-toeing," the abductor hallucis (p. 496) may be excised through a linear incision on the medial side of the foot. Division or lengthening of the tendo calcaneus (p. 480) completes the operation.

It must be remembered that many of the muscles which are involved at first in acute anterior poliomyelitis may subsequently recover, and on this account steps must be taken to prevent the temporarily paralysed muscles from being overstretched by their unaffected antagonists. Deformities which result from the permanent paralysis of some muscle or muscles may be diminished by operative treatment.

Arthrodesis is restricted to cases of widespread paralysis with flail joints.

When the paralysis is more limited, *nerve-anastomosis* or *tendon transplantation*, may be carried out. In the latter operation, either the whole or part of the tendon of an unaffected muscle may be transplanted into the tendon of one of the paralysed muscles, or it may be inserted subperiosteally to a fresh attachment so as to restore the muscular balance of the foot.

The following table shows the position in which tenotomy of the various tendons can be carried out most conveniently :

Tendon.	Position of Incision.
Tibialis Anterior.	At lateral side of tendon, just anterior to the tuberosity of the navicular.
Tibialis Posterior.	At medial side of tendon, proximal to the medial malleolus.
Tendo Calcaneus.	1½ inches (in the child, ½ inch) proximal to its insertion.
Peronæi (Longus and Brevis).	At lateral side of tendons proximal to tip of lateral malleolus.
Extensor Hallucis Longus.	At lateral side of tendon (to avoid injuring the dorsalis pedis), and opposite the tuberosity of the navicular.
Extensor Digitorum Longus and Peronæus Tertius.	At medial side of tendons (to avoid injuring the anterior tibial vessels), either at the ankle-joint or one inch proximal to it.

In each case, after the incision has been made, a blunt-pointed tenotome is introduced between the tendon and the bone on which it lies. The tendon is then stretched across the edge of the knife and divided.

The plantar aponeurosis may be divided through a number of small incisions, made in the neighbourhood of the tightened bands.

Ossification of the Metatarsal Bones and Phalanges.—Each of the metatarsals and each of the phalanges possesses a single epiphysis. In the cases of the second, third, fourth, and fifth metatarsals, the epiphysis forms the rounded head of the bone. It appears during the third or fourth year and unites with the diaphysis at eighteen. In the case of the first metatarsal, the epiphysis forms the base of the bone. It appears during the second or third year and joins the diaphysis at eighteen.

The ossification of the phalanges is similar to that of the first metatarsal. The epiphyses, which appear at the fourth year and fuse at eighteen, form the proximal extremities.

It may be noted that the first metatarsal resembles the phalanges still further in the frequency with which it is attacked by tuberculous disease.

Tuberculous disease of the metatarsals commences near the centre of the diaphysis as an osteo-myelitis, probably owing to the fact that the nutrient artery, on entering the bone, at once divides into a leash of small vessels and not into large ascending and descending branches, as it does in the long bones proper.

The *first metatarsal may be resected* subperiosteally through a dorso-medial incision, which at once exposes the bone. After the periosteum has been freely elevated, the diaphysis is divided near the head and can be wrenched away from the epiphyseal cartilage, which is left behind with the basal epiphysis. In this way the surgeon avoids opening into the tarso-metatarsal and the metatarso-phalangeal joints.

The same method may be followed in resection of any of the other metatarsals, save that the diaphysis must be divided near the base and then wrenched away from the distal epiphysis (p. 93).

In sub-periosteal resection of the proximal phalanges of the lateral four toes, a dorsi-lateral incision is employed to avoid injuring the tendons of the lumbricals, which are inserted into the tibial sides of the phalangeal bases.

In **Hallux Valgus** the great toe becomes excessively adducted and overrides or underlies the second toe. The condition is caused by the wearing of faultily made boots or shoes, which in addition to being too short, have the point of the toe in line with the third instead of in line with the first digit. The toes, therefore, are approximated to one another in the narrow toe of the boot. Once the normal alignment of the great toe is altered, the distortion is increased by the action of the long flexor and extensor tendons. In pronounced cases, these tendons and the lateral metatarso-phalangeal ligament become shortened and the medial part of the head of the first metatarsal is rendered unduly prominent. A bursa, which subsequently develops into a bunion, is formed over the bone.

The condition may be improved by the resection of the distal two-thirds of the head of the first metatarsal. A semilunar incision, the base of which is directed towards the sole, is made over the prominence, and the skin and fascia are elevated together and retracted downwards. The adventitious bursa is dissected free except at its proximal part, so that it can be turned inwards between the first phalanx and the cut surface of the metatarsal. It is stitched in this position, after the head has been excised.

Hallux valgus may be associated with a deformity of the second toe, known as "Hammer Toe." The latter condition may be present alone, affecting the lateral four digits of each foot, and it is then not infrequently congenital in origin. It may, however, be acquired, independently of hallux valgus, by the wearing of boots or shoes which are too short.

The metatarso-phalangeal and the distal interphalangeal joints are hyper-extended, while the proximal interphalangeal joint is acutely flexed. The prominent head of the first phalanx may be excised through a dorsi-lateral incision. The skin and the dorsal extensor expansion, which forms the dorsal ligament of the joint (cf. p. 93), are divided and retracted to the medial side. The proximal interphalangeal joint is thus widely opened, and after the lateral ligament has been divided and the second phalanx still further flexed, the head of the first phalanx may be dislocated into the wound.

Hallux Rigidus, which is not uncommonly associated with flat foot, is due to collapse of the longitudinal arch of the foot. Under normal conditions the long axis of the first metatarsal is directed forwards and downwards, whereas the long axis of the phalanges is parallel to the ground. In hallux rigidus the base of the metatarsal sinks downwards so that its long axis is brought into line with the axis of the phalanges. At the same time the head of the bone becomes rotated upwards and the dorsal portion of its articular cartilage ceases to be articular. This exposed area undergoes fibrous change, and attempts at dorsi-flexion cause severe pain. Reflex spasm of the muscles occurs and the toe is kept rigid.

THE NERVES OF THE LOWER LIMB.

The **Nerves of the Lower Limb** are derived from the lumbar and sacral plexuses (L. 2—S. 3). Plexus injuries are very rare, and with the exception of the common peroneal nerve, the nerves of the lower limb are seldom damaged by violence.

The **Femoral Nerve** (L. 2, 3, and 4) is sometimes injured in gun-shot or stab wounds, or it may be involved by a psoas abscess, but the lesion is rarely complete. The quadriceps femoris is paralysed, and the leg, therefore, cannot be extended, but it can be brought forwards in walking "by using the adductors, after the leg has been everted" (Sherren).

The *sensory disturbance* is most marked over the distal two-thirds of the leg and the adjoining part of the foot, on their medial aspects, *i.e.* over the distribution of the saphenous nerve.

The **Sciatic Nerve** (L. 4, 5, S. 1, 2, and 3) consists of two portions, the tibial (L. 4, 5, S. 1, 2, and 3) and the peroneal (L. 4, 5, S. 1, 2), which, although enclosed in a common sheath in the proximal part of the thigh and in the buttock, are separable up to their origins from the plexus. The sciatic nerve may be injured by penetrating wounds, dislocations of the hip-joint, or fractures of the pelvis. The lesion is usually incomplete, and in 90 per cent of cases (Makins) it is referable to the peroneal part of the nerve.

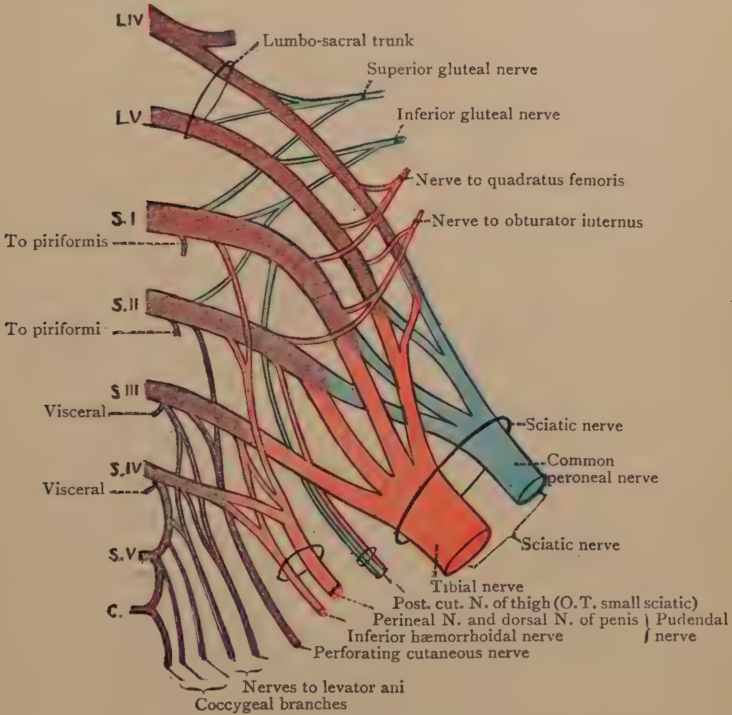
L.IV
Lumbo-sacral trunk
Superior gluteal nerve
L.V.
Inferior gluteal nerve
Nerve to quadratus femoris
S.I
Nerve to obturator internus
To piriformis
S.II
To piriformi
S.III
Visceral
Sciatic nerve
Common peroneal nerve
S.IV
Visceral
Sciatic nerve
S.V
Tibial nerve
Post. cut. N. of thigh (O.T. small sciatic)
C.
Perineal N. and dorsal N. of penis
Inferior hæmorrhoidal nerve
Pudendal nerve
Perforating cutaneous nerve
Nerves to levator ani
Coccygeal branches

FIG. 148.—Diagram of the Sacral Plexus.

When the injury is complete, all the muscles of the leg and foot are paralysed, and if the nerve is divided in the gluteal region, the hamstrings are also involved. Flexion of the leg, however, may be carried out by the gracilis (obturator n.) and the sartorius (femoral n.).

Sensory disturbances are limited to the foot and the lateral aspect of the leg.

The **Common Peroneal Nerve** (L. 4, 5, S. 1 and 2) may be injured in fractures of the neck of the fibula, in scythe wounds and during forcible movements of the ankylosed knee-joint.

The muscles of the anterior and lateral compartments of the leg are paralysed and the foot, therefore, adopts the attitude of talipes equino-varus (p. 500).

When the nerve is injured, proximal to the point of origin of its lateral cutaneous branch (p. 451), alterations in sensibility are found over the dorsum of the foot and the lateral and anterior aspects of the leg, but, when the injury occurs distal to that point, the sensory disturbance is confined to the dorsum of the foot.

The **Tibial Nerve** (L. 4 and 5, S. 1, 2, and 3) is rarely injured, but when it is completely divided, all the muscles of the sole of the foot and of the posterior compartment of the leg are paralysed. The foot, therefore, assumes the attitude of talipes calcaneo-valgus. Loss of sensibility occurs in the skin of the sole of the foot.

The **Obturator Nerve** (L. 2, 3, and 4) may be injured in anterior dislocations of the hip-joint, in obturator herniæ, or during parturition. The injury, however, is very uncommon.

With the exception of the portion of the adductor magnus supplied by the sciatic nerve (p. 415), all the adductor muscles are paralysed, but no sensory disturbance is caused, as the obturator nerve possesses no exclusive area of sensory supply.

The **Lateral Cutaneous Nerve of the Thigh** (L. 2 and 3) possesses an area of exclusive supply over the proximal third of the lateral aspect of the thigh. When the nerve is divided, epicritic and protopathic sensibilities (p. 97) are lost over this area.

The following table shows Kocher's views with regard to the segmental innervation of the muscles of the lower limb (cf. p. 107).

Nerve.	Muscles.
L. 2.	Cremaster.
L. 3.	Psoas major, iliacus, pectineus, sartorius, and the adductors, brevis, longus and magnus.
L. 4.	Quadriceps femoris, gracilis, and (?) obturator externus.
L. 5.	Glutæus medius and minimus; semimembranosus, semitendinosus and biceps.
S. 1.	Glutæus maximus; piriformis, obturator internus and gemelli, quadratus femoris; muscles of anterior and lateral compartments of leg.
S. 2.	Muscles of posterior compartment of leg; muscles of sole of foot.

THE THORAX AND VERTEBRAL COLUMN.

THE THORACIC WALL.

Surface Landmarks.—The *upper border of the manubrium sterni*, which is on the same horizontal level as the fibro-cartilage between the second and third thoracic vertebræ, can be felt in the *jugular* (*supra-sternal*) *notch*.

The junction between the manubrium and the body of the sternum is marked by a transverse ridge, which is known as the *sternal angle* (*of Louis*). The *second costal cartilage* articulates with the sternum at the lateral extremity of the sternal angle and can always be identified with certainty. As the first costal cartilage is obscured by the clavicle, the sternal angle is a valuable landmark when it is necessary to identify the individual ribs.

The anterior halves of the second and third ribs are almost horizontal, and the corresponding interspaces are widest near the sternum. The lower costal cartilages ascend with increasing degrees of obliquity, and the corresponding interspaces are greatest at the junction of the ribs with their cartilages.

The *muscular landmarks* produced by the pectoralis major (p. 2) and the muscles of the back (p. 243) have already been described.

The *apex-beat* of the heart is felt in the fifth intercostal space, 3½ inches from the median plane. It is not always visible, but it can always be felt, especially if it is accelerated and strengthened by slight physical exercise.

Fracture of the Ribs may result either from direct or from indirect violence. *In the former case*, the broken ends are forced inwards. They may penetrate the pleura and wound the lung, or they may pierce the diaphragm and injure the liver or the spleen. Hæmo-thorax, pneumo-thorax, or surgical emphysema may result.

When the injury is due to indirect violence, the thorax being compressed antero-posteriorly, the rib commonly breaks just in front of its angle, and the fragments, which subsequently tend to overlap, are in the first place forced outwards. On this account, there is little danger of injury to the deeper structures.

The Intercostal Spaces are occupied by the *internal and external intercostal muscles*, with their vessels and nerves. The fibres of the external intercostals pass downwards and medially from the lower border of the costal groove of the rib above to the upper border of the rib below. The fibres of the internal intercostals pass downwards and laterally from the upper border of the costal groove of the rib above to the upper border of the rib below.

The *costal groove* is placed on the lower part of the inner surface of the rib and is best marked posteriorly. It lodges an intercostal vein, artery, and nerve, which lie in that order from above downwards so that the nerve is more exposed than the vessels. On this account, when a needle is passed into the chest, the instrument is kept close to the upper border of a rib.

Medial to the costo-chondral junctions the external intercostal muscle becomes a fibro-tendinous sheet, which is termed the *anterior intercostal membrane*. The internal intercostal muscle, although extending to the lateral margin of the sternum in front, is deficient at the vertebral end of the intercostal space, where it is replaced by the *posterior intercostal membrane*.

The lateral extremities of the costal cartilages become enlarged in rickets and form small elevations, which constitute the condition known as the "rickety rosary."

The **Internal Mammary Artery** descends at a distance of half an inch from the side of the sternum. *Posteriorly*, it rests on the costal pleura and, in the lower part of its course, on the slips of the transversus thoracis (triangularis sterni), which pass obliquely from the posterior aspect of the sternum to the upper costal cartilages. *Anteriorly*, the artery is in relation to the costal cartilages and the internal intercostal muscles, and is crossed by the intercostal nerves. At the sixth intercostal space the internal mammary artery ends by dividing into the *superior epigastric* (p. 257), which descends in the sheath of the rectus abdominis and the *musculo-phrenic*, which runs downwards and laterally along the costal origin of the diaphragm.

Ligature of the internal mammary vessels for stab-wounds should be carried out through a transverse incision over the sternal end of the second intercostal space. The pectoralis major is split, and the anterior intercostal membrane and the internal intercostal muscle are divided in the line of the incision. The vessels are then exposed, half an inch from the sternum, lying on the parietal pleura.

A few *lymph glands* are associated with the internal mammary vessels at the medial ends of the second and third intercostal spaces (p. 26).

In the operation of **Paracentesis Thoracis** an exploring needle is introduced into the pleural sac through one of the intercostal spaces overlying the dull area. In order to avoid injuring the intercostal vessels and nerve, the needle is inserted close to the upper border of the rib which forms the lower boundary of the space selected. When the puncture is made through the lower part of the thoracic wall, the needle should be directed upwards and inwards as soon as it enters the pleural sac, lest the diaphragm be penetrated. During the operation the skin over the selected space is drawn upwards so that, when the needle is withdrawn, the track of the puncture is practically obliterated.

In **Empyæma** an incision is made along the eighth or ninth rib, with its centre in the posterior axillary line. During the operation, the patient lies on the sound side with the arm of the other side flexed and adducted. In this position the inferior angle of the scapula is drawn forwards and upwards, and the seventh rib is exposed. Care must be taken to make certain that the incision is not made over the seventh rib, as the wound would be subsequently obstructed by the scapula when the arm resumed its normal position.

The skin and fasciæ and the lower border of the latissimus dorsi, which is exposed in the posterior part of the incision, are all divided, and the wound is deepened through the serratus anterior. The rib is then exposed and an incision is made through the periosteum in its long axis. A transverse cut is made at each extremity of this incision, and the periosteum is then stripped off both surfaces of the rib. A portion of the rib can be resected without injuring the intercostal vessels and nerves. The wound is then deepened through the inner layer of the periosteum and the costal pleura. The pus must not be allowed to escape too rapidly as the sudden diminution of pressure may lead to heart-failure. A large tube is *fixed* in position and the edges of the wound are drawn together.

When it is necessary to resect one of the lower ribs, the position of the lower limit of the pleural sac (p. 516) and the fact that the costo-diaphragmatic recess may be obliterated by adhesions must be remembered. Otherwise the diaphragm may be divided and the peritoneal cavity opened.

The same method of approach may be employed when a rib is the site of tuberculous disease. As much of the infected bone and of the periosteum on the outer surface is removed as may be necessary, but the periosteum on the internal surface, after being carefully scraped, is left otherwise intact and the skin wound is then closed.

When the lung has been collapsed for some time in the presence of a chronic empyæma, *extensive resection of ribs* (Estlander, Schede, and Kocher) may be performed to allow the chest wall to fall in and obliterate the persistent cavity.

A large semilunar incision is made over the lateral aspect of the chest so that its lowest part corresponds to the bottom of the cavity. The anterior extremity of the incision may extend upwards to the lower border of the pectoralis major, and its posterior extremity may ascend between the vertebral border of the scapula and the vertebral spines. In the latter case, the latissimus dorsi, the trapezius, and the rhomboids are all divided. The U-shaped flap thus marked out consists of all the soft parts down to the ribs. When it is retracted upwards, portions of the second to the eighth or ninth ribs may be resected from their angles to their costal cartilages. The periosteum and the thickened parietal pleura are also removed so that the chest wall may be able to fall in upon the collapsed lung.

In certain cases the lung may be decorticated of its thickened visceral pleura in the hope that it may be able to re-expand.

THE THORACIC CONTENTS.

The Pleuræ.—Each lung is enclosed in a serous membrane, termed the **pleural sac**. The pleural membrane consists of a *visceral layer*, which is closely adherent to the lung and lines the fissures in its substance, and a *parietal layer*. The two pleural sacs are separated from one another by the **mediastinal space**, which contains the heart, the great vessels, the trachea, the œsophagus, etc., and those parts of the pleural membrane

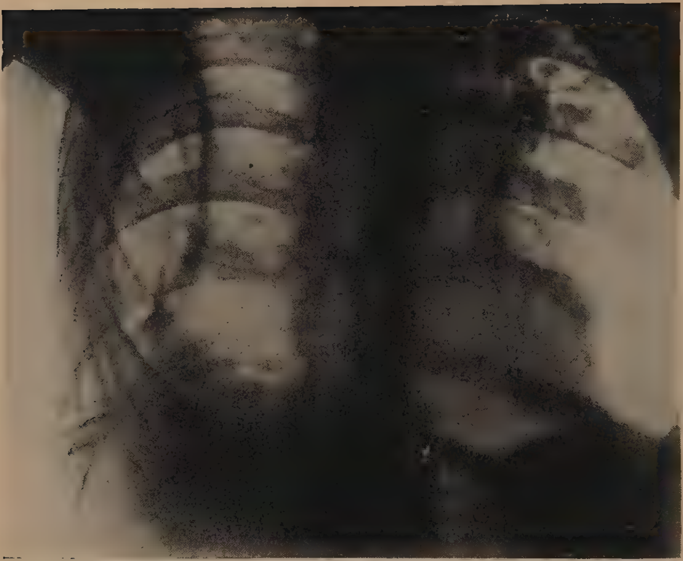

FIG. 149.—Radiogram showing a right-sided Pneumothorax. Observe the dark line due to the collapsed lung.

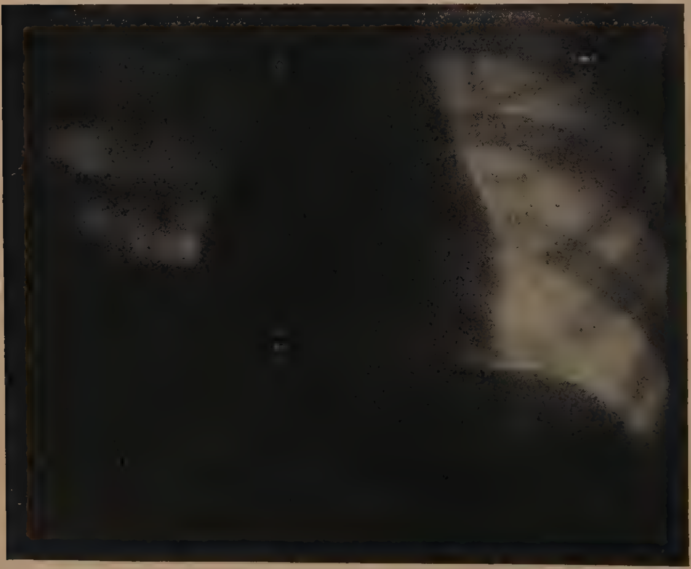

FIG. 150.—Radiogram showing the presence of an Empyæma in the right pleural sac.

which form the lateral boundaries of the mediastinum are termed the *mediastinal pleuræ*.

When the arrangement of the pleura is examined in a transverse section of the thorax at the level of the fourth thoracic vertebra, it is seen that the costal pleura lines the inner surfaces of the ribs and, anteriorly, it passes medially behind the sternum to the median plane. The membrane is then reflected backwards over the great vessels till it reaches the vertebral column.

If the section is made at a slightly lower level (Fig. 151), it passes through the root of the lung. On passing backwards from the sternum, the mediastinal pleura clothes the pericardium and reaches the anterior aspect of the root of the lung, on which it is carried laterally to become continuous with the visceral pleura. After covering the lung, the pleura is carried medially on the posterior aspect of the root and again reaches the pericardium, on which it passes backwards to the vertebral column.

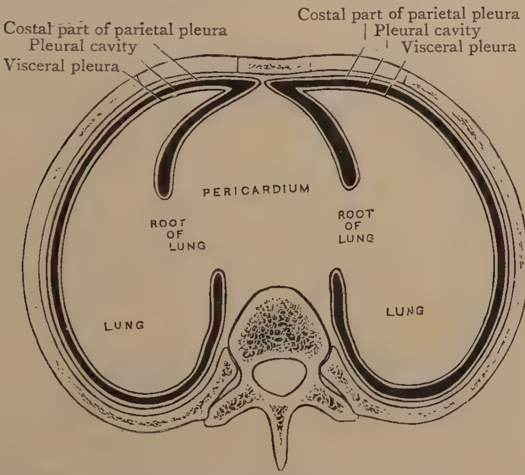
Costal part of parietal pleura
Pleural cavity
Visceral pleura
Costal part of parietal pleura
Pleural cavity
Visceral pleura
PERICARDIUM
ROOT OF LUNG
ROOT OF LUNG
LUNG
LUNG

FIG. 151.—Diagram of a Transverse Section through the Thorax, at the Level of the Root of the Lung.

When a frontal section is examined, it is found that, when the costal pleura is traced downwards, it extends for some distance below the lower border of the lung and is then reflected on to the diaphragm. In this inferior extremity of the pleural sac, which is termed the phrenico-costal sinus, the costal and diaphragmatic pleuræ are in immediate contact with one another for a considerable distance during ordinary quiet inspiration.

The costal pleura becomes continuous with the mediastinal pleura not at one point only, as in Fig. 151, but along a line termed the *costo-mediastinal line of pleural reflection*, and similarly the costal pleura becomes continuous with the diaphragmatic pleura along a line which is termed the *costo-diaphragmatic line of pleural reflection*. These lines indicate the limits of the pleural sacs, and their relation to the surface of the body is of great importance.

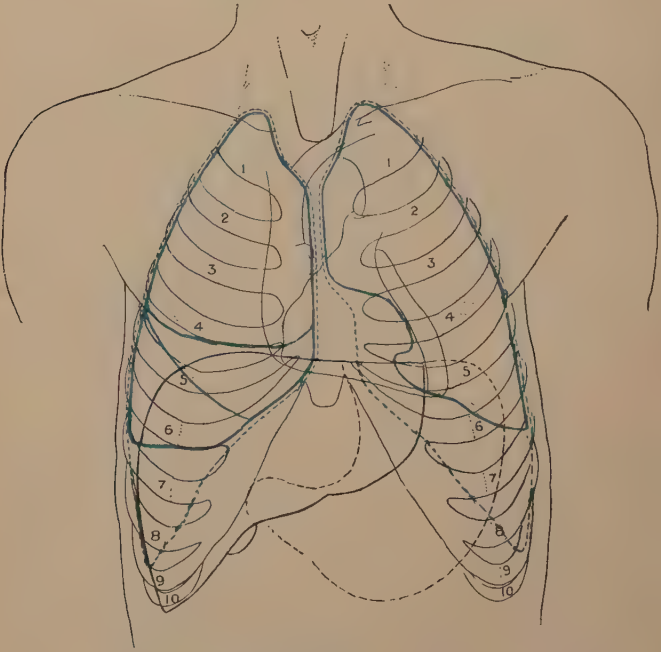

FIG. 152.—Surface Relations of the Liver, Stomach, Lungs, Heart and Pleural Sacs.

Blue line = outline of lung. Dotted blue line = lines of pleural reflection. Fine black line = heart and great vessels. Heavy black line = liver. Dotted black line = stomach.

Superiorly, the pleura bulges upwards for about one inch above the sternal end of the clavicle into the root of the neck. In this area the apex of the lung is in close contact with the parietal pleura, which separates it from the subclavian artery (p. 146).

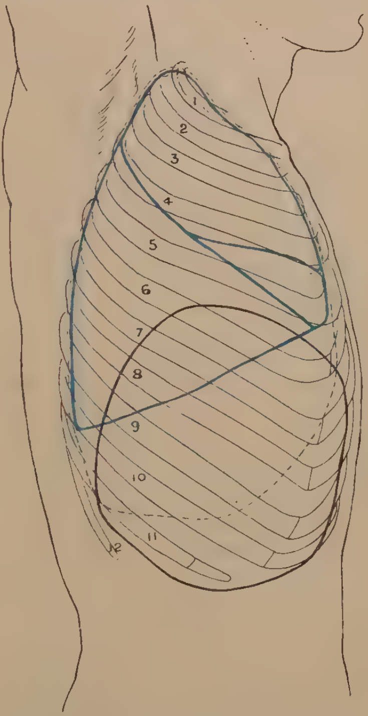

FIG. 153.—Surface Relations of Right Lung, Pleural Sac and Liver, from the Lateral Aspect.

Blue line = the lung and its fissures.
Dotted blue line = pleural sac.
Heavy black line = liver.

Surface Relations of the Lungs and Pleural Sacs. — The **Cervical Pleura** can be indicated on the surface by a curved line, with an upward convexity, drawn from the centre of the sterno-clavicular joint to the junction of the sternal and middle thirds of the clavicle. The summit of the convexity should not be more than one inch above the clavicle (Fig. 152).

The **Costo-Mediastinal Line of Pleural Reflection** is not the same on both sides of the body. On the *right side* it commences above at the sterno-clavicular joint and passes downwards and medially to the centre of the manubrium sterni. From that point it descends vertically, in or near the median plane, to the level of the sixth costal cartilage, where it becomes continuous with the costo-diaphragmatic line of reflection. On the *left side,* the line of reflection is similar until the level of the *fourth* costal cartilage is reached. At that point it deviates laterally to the left border of the sternum, down which it descends to the sixth chondro-sternal articulation, where it becomes continuous with the costo-diaphragmatic line of reflection.

In the interval which is left between the two pleural sacs behind the lower part of the left half of the sternum, the pericardium comes into direct contact with the anterior thoracic wall (p. 517).

The **Costo-Diaphragmatic Line of Pleural Reflection** indicates the lowest limit of the pleural sac. Although sometimes a little lower on the left side, it may, for practical purposes, be mapped out on the surface on the two sides of the body by similar lines. It begins at the lower end of the costo-mediastinal line and passes laterally and downwards behind the seventh costal cartilage and the seventh intercostal space. *In the lateral line* (*mid-clavicular or mammary*), the costo-diaphragmatic line crosses the *eighth rib*, at its junction with its cartilage. It continues to descend slightly as it passes round the body, and in the *mid-axillary line* it cuts the *tenth rib*. On the posterior aspect of the trunk the line of reflection ascends slightly as it passes towards the vertebral column, and crosses the eleventh and *twelfth ribs*, *the latter at the point where it is crossed by the lateral border of the sacro-spinalis* (see also p. 279). It reaches the vertebral column at the level of the twelfth thoracic spine, *i.e.* nearly half an inch below the head of the twelfth rib (Fig. 84).

The Lower Border of the Lung lies at a much higher level than the costo-diaphragmatic line during quiet respiration. In the *lateral* (*mammary*) *line* the lower border of the lung crosses the *seventh rib* and lies about 1½ inches above the lower limit of the pleura. In the *mid-axillary line* the difference is most marked and a distance of three or four inches separates the lower border of the lung, which is placed on the *eighth rib*, from the lower limit of the pleural sac. *Posteriorly* the difference is not so great, but the phrenico-costal sinus extends usually two inches below the lower border of the lung, which corresponds to the *tenth thoracic spine* (Fig. 84). On the right side of the body the phrenico-costal sinus is related to the liver and, posteriorly, to the upper pole of the right kidney (p. 279). On the left side it comes into relation successively with the left lobe of the liver, the stomach, the spleen (p. 323), and the upper pole of the left kidney.

The **Anterior Border of the Right Lung** is straight and coincides with the costo-diaphragmatic line of pleural reflection. The **Anterior Border of the Left Lung** possesses a deep notch at its lower end, which falls short of the lateral margin of the sternum by at least one inch. At the sternal ends of the fourth and fifth spaces and behind the sternal ends of the fifth and sixth cartilages of the left side, the pericardium is only separated from the chest wall by a double layer of pleura. Light percussion of this area, therefore, produces a dull note, and the area will be increased in size when the anterior border of the left lung is retracted owing to pressure or disease (see below).

The Heart and Pericardium.—The **Pericardium** is a fibro-serous sac which encloses the heart and the roots of the great vessels. Under normal conditions its outline corresponds to the outline of the heart, but, when greatly distended, it becomes pear-shaped with the blunted apex superiorly.

The **Right Border of the Heart** is entirely formed by the right atrium (auricle). It begins above at the third right costal cartilage half an inch lateral to the sternum, and descends, with a slight convexity to the right, to the sixth costal cartilage. Its maximum distance from the median plane is in the fourth interspace and amounts to 1½ inches.

The **Lower Border of the Heart** extends from the lower end of the right border to the apex-beat (p. 508). It is formed mainly by the right ventricle, but the left ventricle forms its left extremity.

The **Left Border of the Heart** extends upwards and medially from the apex to the second left intercostal space, where it lies at a distance of half an inch from the sternum. It is gently convex upwards and to the left, and corresponds to the rounded border of the left ventricle.

When the heart, pleuræ, and lungs are marked in on the same chest (Fig. 152), it will be found that an irregularly triangular area of the anterior surface of the heart is uncovered by the left lung. This area is termed the area of *superficial cardiac dulness*, and where it extends beyond the sternum it is covered by pleura.

Effusion of fluid into the pericardial sac may greatly increase the size of the area of superficial cardiac dulness, and the lungs and pleural reflections are displaced laterally. Curschmann holds that it is not safe to perform *paracentesis pericardii* at the lateral border of the sternum, as the fluid tends to collect posteriorly and laterally, so that the heart is thrust forwards against the chest-wall. He recommends that the needle should be inserted in or lateral to the lateral line, and passed, in a medial and backward direction, through the anterior part of the left pleural sac.

When the effusion is purulent, *exposure and drainage of the pericardium* is rendered necessary. A curved flap is turned upwards and to the left, exposing the left half of the lower part of the sternum and the costal cartilages of the fifth and sixth ribs. The sixth costal cartilage is carefully removed piecemeal and the internal mammary vessels (p. 509) are exposed lying on the transversus thoracis (triangularis sterni). When they have been ligated, the transversus thoracis is divided and the pericardium is exposed with a thin covering of mediastinal fat. If necessary, the fifth costal cartilage and the intercostals may be removed. The fat is wiped away, and the left pleural reflection is identified and displaced laterally with the fingers. The pericardium can then be opened and drained.

In *suture of the heart* for stab-wounds good access is essential and is obtained by a modification of the approach described above. The incision is larger and an extensive flap of the chest-wall may be turned up, by dividing the third, fourth, fifth, and sixth ribs after their costal cartilages have been cut through near the sternum.

The Œsophagus begins opposite the sixth cervical vertebra and descends through the neck, lying behind the trachea and in front of the vertebral column (p. 143). In the upper part of the thorax it projects slightly beyond the left side of the trachea and, opposite the fifth thoracic vertebra, it is crossed anteriorly by the left bronchus. Below that point, the œsophagus lies behind the pericardium and in front of the vertebral column, but it curves forwards away from the latter as it leaves the thorax. The œsophagus passes through the diaphragm opposite the tenth thoracic vertebra, and its abdominal part, which is only half an inch in length, ends at the cardiac orifice of the stomach.

The œsophagus is slightly *constricted at its commencement*, which lies six inches from the incisor teeth, and again *at the point where it is crossed by the left bronchus*, which lies four inches lower down. It possesses a third constriction *as it passes through the opening in the diaphragm*, which is sixteen inches distant from the incisor teeth. Œsophageal bougies should be graduated from the distal extremity so that the surgeon may locate the position of an œsophageal obstruction. In healthy subjects some obstruction may be encountered at the lower end of the pharynx, and it is caused by the bougie impinging against the upper border of the posterior part of the cricoid cartilage. If the patient swallows, the instrument readily slips past the obstruction. At a distance of rather more than sixteen inches from the incisor teeth, the bougie enters the cardiac orifice of the stomach.

Opposite the fourth thoracic vertebra, the œsophagus is crossed anteriorly by the aortic arch and, in cases of œsophageal obstruction, the possibility that the condition may be caused by aneurismal pressure must be excluded before a bougie is passed.

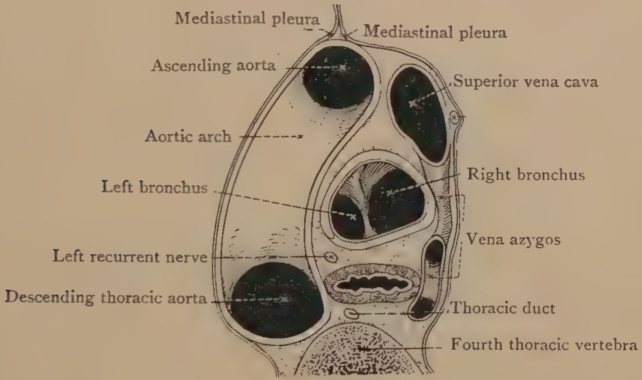
Mediastinal pleura
Mediastinal pleura
Ascending aorta
Superior vena cava
Aortic arch
Right bronchus
Left bronchus
Vena azygos
Left recurrent nerve
Descending thoracic aorta
Thoracic duct
Fourth thoracic vertebra

FIG. 154.—Transverse Section through the Thorax at the Level of the Fourth Thoracic Vertebra.

Malignant disease of the œsophagus commonly occurs at the three places where the tube is normally constricted, and, when it is situated in the upper thoracic region, the growth may compress the left recurrent nerve, which ascends in the groove between the left side of the trachea and the œsophagus (Fig. 154). In this situation, too, it may perforate the left bronchus and give rise to septic pneumonia.

When the lower end of the thoracic part of the œsophagus is the site of new growth, the disease may invade the right pleural sac and cause an empyæma.

THE POSTERIOR THORACIC WALL.

Costo-Vertebral Joints.—The vertebral end of each typical rib (second-ninth) articulates with the vertebral column by two separate joints. The *head of the rib* articulates with the upper part of the body of the vertebra to which it corresponds numerically, with the lower part of the vertebra above, and with the fibro-cartilage between them. The *tubercle of the rib* articulates with the transverse process of the vertebra to which it corresponds numerically, and this joint is strengthened by a strong ligament (*the ligamentum colli costæ—intercosto-transverse*) which connects the posterior aspect of the neck of the rib to the anterior aspect of the transverse process (Fig. 155).

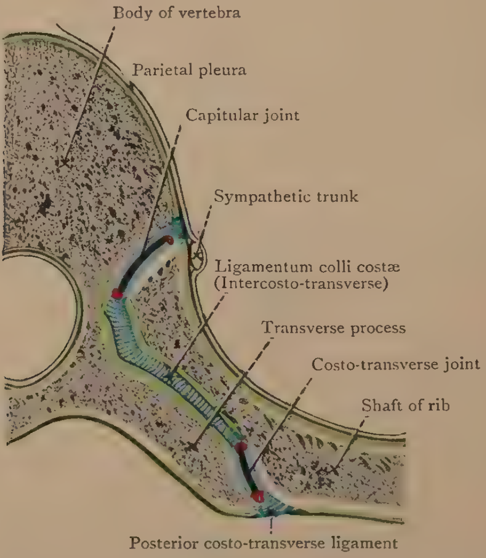
Body of vertebra
Parietal pleura
Capitular joint
Sympathetic trunk
Ligamentum colli costæ
(Intercosto-transverse)
Transverse process
Costo-transverse joint
Shaft of rib
Posterior costo-transverse ligament

FIG. 155.—Transverse Section through a Typical Costo-Vertebral Articulation.

Light blue = articular cartilage.
Striped blue = ligaments.
Green = periosteum.
Red = synovial membrane.

Surgical Approach to the Posterior Mediastinum.—Tuberculous disease or abscess affecting the thoracic vertebræ may be attacked by the operation of **Costo-Transversectomy**, in cases where conservative treatment has failed and where paralytic signs have not improved with rest, or when radiograms suggest the presence of sequestra. As the result of the disease, a certain degree of angular curvature is present, and the incision begins near the most prominent spine. It is carried laterally along the rib below, which is to be resected, and all the soft structures are divided until the rib and the transverse process with which it articulates are exposed. The periosteum is elevated and the rib is divided lateral to its tubercle. The transverse process is divided at its medial end and can be disarticulated, after the ligamentum colli costæ and its other connections have been divided. The neck of the rib can then be cut through close to the head. In the last-named step care must be taken to leave the head of the rib intact, lest the sympathetic trunk, *which descends on the heads of the ribs*, be injured. The periosteum on the inner surface of the rib is next divided and the pleura, which is now exposed, is retracted. A finger can then be passed medially towards the vertebral bodies, and it should be remembered that the disease is most advanced in the vertebra above the one to which the resected rib corresponds numerically.

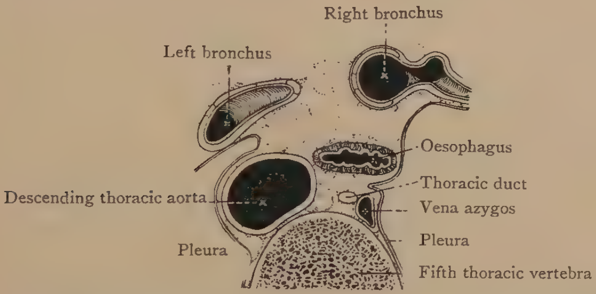

FIG. 156.—Diagram of a Transverse Section through the Upper Part of the Posterior Mediastinum.

On the right side of the vertebral column the finger meets with no obstruction, but below the level of the third thoracic vertebra *on the left side* the descending thoracic aorta is encountered (Fig. 156).

Exposure of the Œsophagus.—In the removal of a foreign body from the œsophagus or a bronchus, or in excision of a carcinoma of the œsophagus, the mediastinum must be exposed more widely. Access is obtained by reflecting a large musculo-cutaneous flap, about four inches wide, which has its base over the vertebral spines. When the upper part of the œsophagus is attacked, the flap extends from the first to the seventh intercostal space. The medial portions of four ribs are resected subperiosteally, and after the intercostal vessels have been ligated the periosteum and intercostal muscles are carefully incised at the medial part of the wound.

Owing to the position of the descending thoracic aorta (Fig. 156) this operation is usually performed *on the right side,* and it must be remembered that the right pleural sac forms a small recess behind the right border of the œsophagus (Fig. 156).

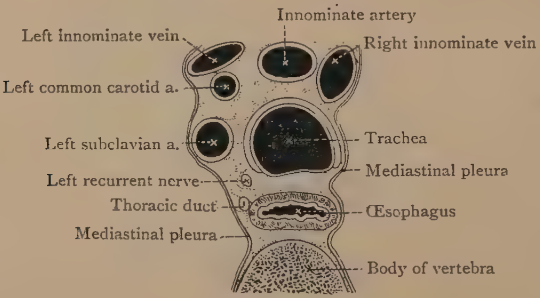
Innominate artery
Left innominate vein
Right innominate vein
Left common carotid a.
Left subclavian a.
Trachea
Mediastinal pleura
Left recurrent nerve
Thoracic duct
Œsophagus
Mediastinal pleura
Body of vertebra

FIG. 157.—Transverse Section through the Superior Mediastinum.

The pleura is stripped off the heads of the ribs, the side of the vertebral column, and the œsophagus, and, if this is done carefully, there is little danger of injuring the sympathetic trunk, which descends on the heads of the ribs. The œsophagus, which can, if necessary, be identified by passing an œsophageal bougie, can now be freed and brought to the surface, a distance of about four inches.

When the œsophagus is exposed on the right side *below the root of the lung,* care must be taken not to injure the vagus nerve, which descends along its lateral border. In this situation the *vena azygos* and the *thoracic duct,* which lie behind the œsophagus, are not likely to be injured, as they tend to remain in contact with the vertebral column when the pleura is stripped away and the œsophagus is brought to the surface. At the upper border of the root of the right lung the vena azygos turns forwards, crossing the lateral aspect of the œsophagus to enter the superior vena cava, and, if necessary, it may be ligatured in this part of its course.

In the upper part of the thorax the œsophagus lies slightly to the left of the median plane, and, as it is situated above the arch of the aorta, *it may be approached from the left side.* When the pleura is stripped off the vertebral column and retracted, the sympathetic remains intact on the heads of the ribs, but the *thoracic duct* and the *left recurrent nerve* are exposed to injury. In this part of its course the thoracic duct is closely applied to the left border of the œsophagus, and it should be identified and separated before the œsophagus is freed. As the vagus crosses the arch of the aorta it gives off the left recurrent nerve, which ascends behind the vessel, to the left of the trachea and in front of the left edge of the œsophagus (Fig. 157). The *left subclavian artery* passes upwards, backwards, and to the left from the aortic arch, and opposite the second thoracic vertebra it is in close contact with the lateral border of the œsophagus, from which it is separated by the thoracic duct. The position of this large vessel must be kept in mind while the œsophagus is being freed.

THE VERTEBRAL COLUMN AND THE SPINAL MEDULLA.

Ossification of the Vertebræ.—Each typical vertebra possesses three primary centres of ossification—one for the body, and one for each half of the vertebral arch. The two halves of the vertebral arch unite with each other posteriorly, and this process, which begins in the cervical region at the end of the first year, extends very gradually to the other regions, so that it is not completed in the sacrum till between the seventh and tenth years. The vertebral body is separated from the vertebral arch on each side by a bar of cartilage, which is termed the neuro-central synchondrosis, and it disappears about the third or fourth year.

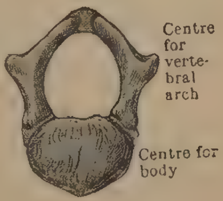

FIG. 158.—Ossification of a Vertebra.

In some cases the neuro-central synchondrosis may persist, especially in the lumbar region. In the interpretation of radiograms of the vertebral column, care must be taken not to mistake this anomaly for a fracture.

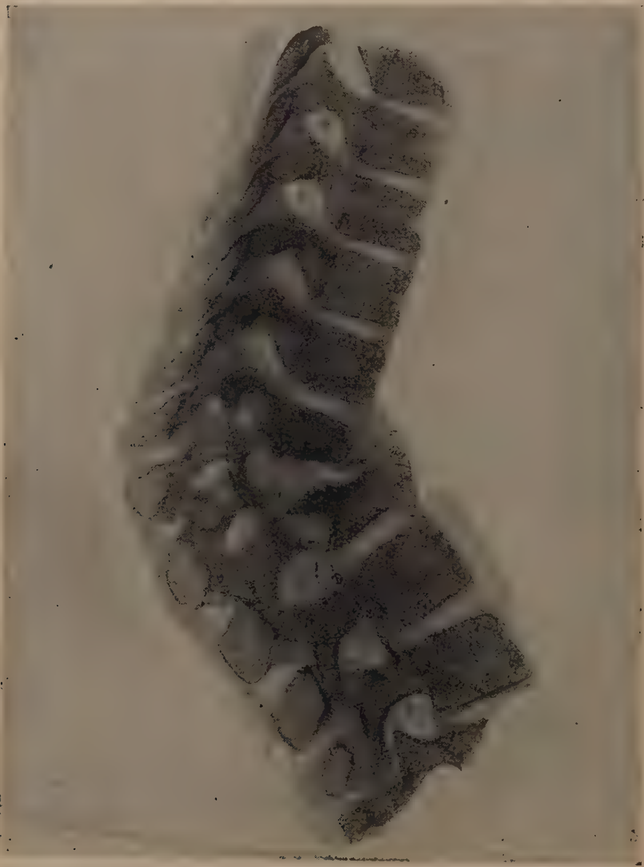

FIG. 159.—Kyphosis, produced by Tuberculous Disease of Thoracic Vertebræ. (From a specimen with ribs removed.)

Five secondary centres appear at puberty, and the epiphyses so formed unite with the rest of the bone at twenty-five. They are placed at the extremities of the spine and the transverse processes and on the superior and inferior aspects of the body. The two latter form ring-like epiphyses and do not extend over the whole of the surfaces on which they are situated.

The tendency for *tuberculous disease* to attack growing bone is well illustrated by the frequency of Pott's disease in childhood compared with its comparative rarity after puberty. The infection being carried by the blood-stream, the disease begins as an osteo-myelitis near the anterior surface of the body, because the nutrient artery enters the body posteriorly and breaks up into a leash of small vessels about its centre. Owing to the absence of complete epiphyseal plates, it readily spreads to the adjoining vertebræ.

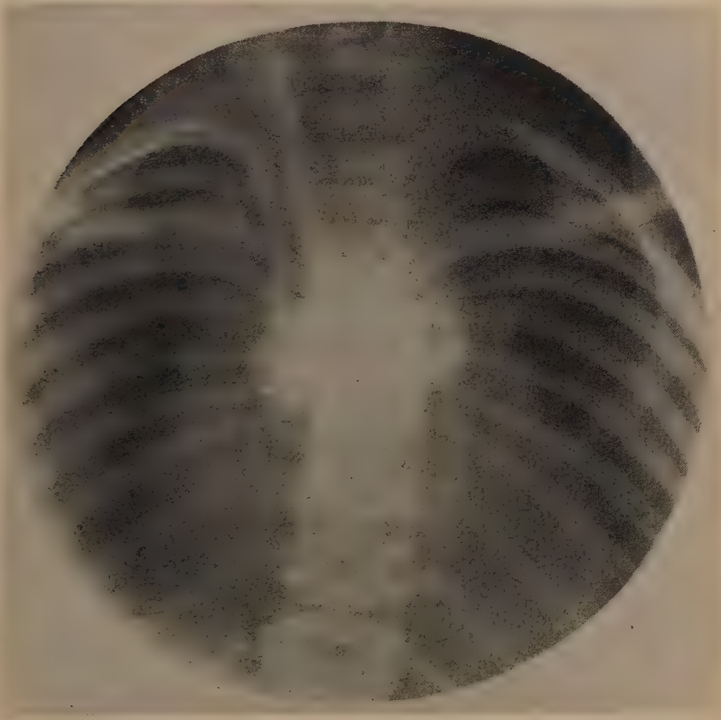

FIG. 160.—Pott's Disease in Thoracic Region of a Child. The abscess is undergoing calcification and absorption.

If the disease spreads forwards, the anterior part of the vertebral body is destroyed and collapses, but the posterior part does not give way to the same extent owing to locking of the healthy articular processes. As a result, the part of the vertebral column above the disease is bent forwards on the part below, giving rise to angular curvature (Fig. 159).

When the disease spreads backwards, the pus may erupt through the periosteum and the posterior longitudinal ligament into the vertebral canal, where it lies outside the dura mater and may compress the spinal medulla. If the disease occurs before the age of five, it is prevented by the neuro-central synchondroses from spreading postero-laterally into the vertebral arch (Fig. 158).

The *periosteal type of the disease* affects the anterior surfaces of the bodies of several adjoining vertebræ and results in a gradual collapse, which tends to produce a gentle curvature of the vertebral column rather than a sharp angular curvature.

Joints at the Upper End of the Vertebral Column.—The **Atlas**, or first cervical vertebra, has no body, and it consists of a short *anterior arch* and a longer *posterior arch*, connected to one another on each side by the *lateral mass*. The superior surfaces of the lateral masses articulate with the condyles of the occipital bone, and at this joint only nodding movements of the head are possible.

The inferior surfaces of the lateral masses articulate with the superior articular facets of the second cervical vertebra. The **Dens (Odontoid Process)**, which represents the body of the atlas, projects upwards from the body of the second cervical vertebra. Its anterior surface articulates with the posterior surface of the anterior arch of the atlas, and it is held in position by the *transverse ligament*, which connects the two lateral masses and is separated from the posterior surface of the dens by a small bursa (Fig. 50).

In rotatory movements of the head, the atlas, which carries the skull with it, moves on the second cervical vertebra.

Tuberculous disease not uncommonly originates in the body of the second cervical vertebra or in the dens. From the latter situation it may spread *forwards* and infect the articulation between the dens and the atlas; or, it may spread *backwards* and infect the bursa between the dens and the transverse ligament. These joints are supplied by branches from the first and second cervical nerves, which also supply the muscles which rotate the head. Irritation of the branches of these nerves leads to reflex phenomena. Pain is experienced over the cutaneous distribution of the second cervical nerve (Fig. 72)—the first cervical nerve has no cutaneous branches—and the head is kept rigid owing to muscular spasm.

If the transverse ligament is destroyed or the dens eroded, the head slips forwards and the spinal medulla (spinal cord) is crushed. Death results as the injury occurs above the level of the origin of the phrenic nerve (p. 537).

When the body of the third or fourth cervical vertebra is the site of the disease, the same rigidity from muscular spasm is present, and pain is experienced over the cutaneous distribution of the third and fourth cervical nerves. These symptoms are due to pressure on the nerves themselves as they pass out from the vertebral canal, unless the joints between the articular processes are involved, in which case they may be entirely reflex.

Vertebral Caries.—In abscess formation, the pus may escape to one or other side of the anterior longitudinal ligament, which connects the anterior surfaces of the vertebral bodies to one another, or it may perforate the ligament. It then gives rise to a *retro-pharyngeal abscess*, which can readily be recognised on palpation of the posterior wall of the pharynx with the finger. The abscess destroys the longus colli and comes to lie behind the prevertebral fascia. It may extend laterally (p. 115) into the floor of the posterior triangle (Fig. 36), and its subsequent course is described on p. 116.

The abscess may be *approached* through an incision along the posterior border of the sterno-mastoid, which is retracted forwards along with the carotid sheath (Chiene). The anterior tubercles on the transverse processes are palpated and the abscess is opened, slightly to their medial side, by Hilton's method (cf. evacuation of acute retro-pharyngeal abscess, p. 116).

When the disease involves the lower cervical and upper thoracic vertebræ, the affected part of the vertebral column is held rigid by muscular spasm. Referred pain is experienced in the upper limbs (Fig. 14) and its distribution may help to determine the precise site of the disease. In advanced cases *angular curvature* may be present. When an abscess forms, the pus tends to track downwards behind the anterior longitudinal ligament or the prevertebral fascia into the mediastinum. Following the course of the dorsal branch of an intercostal vessel, it may ultimately point through the muscles of the back.

When the disease originates in the mid-thoracic region, muscular spasm produces boarding and rigidity of the sacrospinales and, sometimes, the abdominal muscles. Pain may be experienced in the back, but it is very frequently referred to the *anterior* abdominal wall, and it may then lead to errors in diagnosis. Abscesses may point through the muscles of the back, or they may follow the course of an intercostal nerve and come to the surface by tracking along its lateral cutaneous branch (Fig. 161).

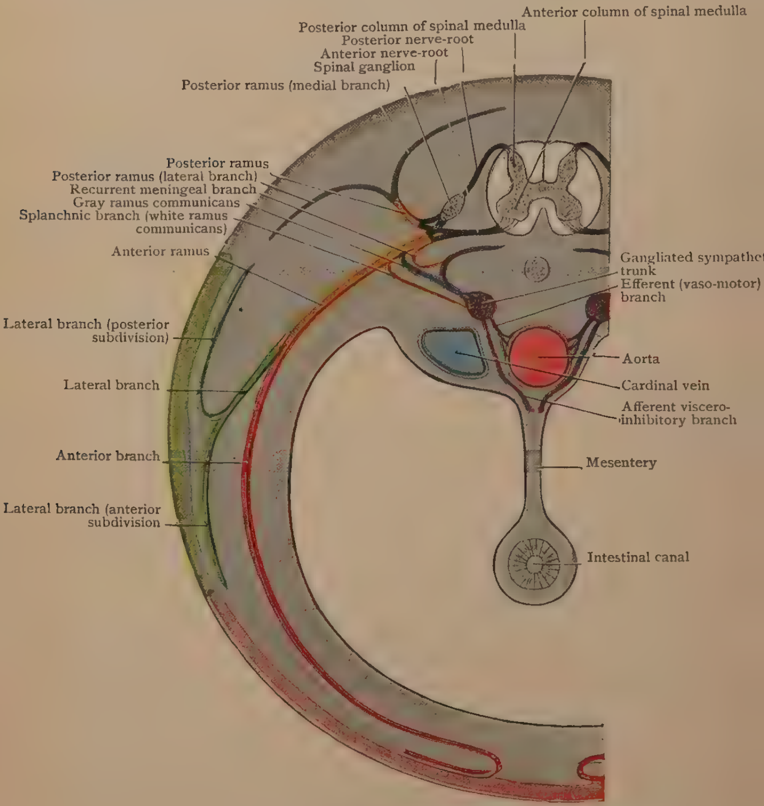
Anterior column of spinal medulla
Posterior column of spinal medulla
Posterior nerve-root
Anterior nerve-root
Spinal ganglion
Posterior ramus (medial branch)
Posterior ramus
Posterior ramus (lateral branch)
Recurrent meningeal branch
Gray ramus communicans
Splanchnic branch (white ramus communicans)
Anterior ramus
Lateral branch (posterior subdivision)
Lateral branch
Anterior branch
Lateral branch (anterior subdivision
Gangliated sympathet
trunk
Efferent (vaso-motor) branch
Aorta
Cardinal vein
Afferent viscero-inhibitory branch
Mesentery
Intestinal canal

FIG. 161.—Scheme of the Distribution of a Typical Spinal Nerve.

Abscesses in connection with the lower thoracic vertebræ may enter the posterior mediastinum and gravitate downwards behind the medial lumbo-costal arch (internal arcuate ligament, p. 276). They subsequently descend under the fascial covering of the psoas major.

When the disease commences in the lumbar region, referred pain may be experienced in the back, in the lowest part of the anterior abdominal wall, in the anterior, medial, or lateral apects of the thigh, or in the medial aspect of the leg (Figs. 118 and 124). Deep hyperalgesia may be found in any of these areas and muscular spasm may also be present.

Abscesses arising in connection with the lumbar vertebræ may spread laterally and point in the loin (Fig. 83); *or,* they may descend behind the fascial covering of the psoas major and follow the femoral nerve into the thigh; *or,* they may follow the gluteal or sciatic nerves and enter the buttock (see also p. 422).

Paraplegia may come on at any stage of tuberculous disease of the vertebral column, but it occurs most frequently when the upper thoracic region is involved. It is not as a rule due to bony pressure, for, although the angular curvature may be so marked that the spinal medulla is actually compressed, this condition arises so gradually that it does not lead to paralysis. Paraplegia is usually caused by a backward spread of the disease into the vertebral canal. Tuberculous pachymeningitis, or an abscess, or a sequestrum may compress the spinal medulla and give rise to paralysis of the lower limbs. The signs of this condition are outlined on p. 536.

Examination of the Vertebral Column.—In suspected cases of tuberculous disease, the examination of the vertebral column must be carried out systematically by means of both active and passive movements. The active movements of flexion, extension, rotation, and lateral flexion are first examined and any limitation is observed. The patient is then placed face downwards on the table and passive movements are carried out by acting on the vertebral column through the lower limbs and pelvis. A positive diagnosis depends, to a large extent, on the discovery of abnormal rigidity due to muscular spasm. At an early stage no local pain can be elicited by pressure over the spines, as the disease originates in the anterior part of the vertebral bodies. The sensitiveness to deep pressure should always be tested, as areas of muscular hyperalgesia are frequently present in the muscles supplied by the segment involved.

Curvatures of the Vertebral Column.—In the fœtus the vertebral column shows two *primary curves*, both concave forwards. Of these, one extends from the head to the pelvis and the other affects the sacral region. When the child begins to sit up and elevate its head, a forward convexity appears in the cervical region; and, when the erect attitude is assumed and the child begins to walk, a forward convexity appears in the lumbar region also. The development of these *secondary curves* enables the vertebral column to transmit the weight of the trunk to the pelvis in such a way that little or no muscular effort is required to maintain the erect attitude.

The amount of movement possible between any two adjoining vertebræ is very small, but by the summation of these movements aided by the compressibility of the intervertebral fibro-cartilages, the vertebral column, as a whole, acquires a moderately extensive range of movement. In flexion and extension of the vertebral column the lumbar and cervical regions move more freely than the thoracic region, but the reverse is the case with regard to rotation, except in the case of the joints between the atlas and the second cervical vertebra. Lateral flexion occurs chiefly in the lumbar region.

In weakly children and debilitated adolescents, the body may grow more rapidly than the muscles which support it. These patients instinctively adopt attitudes which relieve the tired muscles and throw the strain on the ligaments of the intervertebral joints. The habitual adoption of such attitudes causes overstretching of the ligaments on which the strain is thrown, and the opposing ligaments become shortened. There is, therefore, a tendency for the faulty attitude to be maintained mechanically. When the proper alignment of the vertebral column is altered, the muscular balance is upset. One group of muscles obtains a mechanical advantage over the corresponding antagonistic group, which consequently becomes overstretched. As a result, abnormal curves appear in the vertebral column.

Lateral Curvature, or **Scoliosis**, occurs primarily in the thoracic region and its convexity is usually directed to the right side. *Compensatory curves*, which are convex in the opposite direction, appear above and below the primary curve, and they serve to maintain the equilibrium of the body. The lateral curvature of the thoracic region is not produced by true lateral flexion of the vertebral column, as this movement is restricted to the lumbar region. The thoracic vertebræ become rotated and, at the same time, extended. Owing to the coincident occurrence of rotation, the movement of extension produces a lateral curvature instead of a diminution of the normal forward concavity. The vertebral spines lie in the concavity of the curve and, as they are close to the median plane, the apparent amount of lateral curvature, as estimated by examination of the spines, is much smaller than the actual amount.

In the later stages, the unequal distribution of pressure hinders growth in what was originally the posterior part of the body, and the vertebral bodies become wedge-shaped.

The direction of the ribs is necessarily affected by the rotation of the thoracic vertebræ. On the convex side of the curve, the ribs produce a " hump " on the dorsal aspect of the body and cause elevation of the scapula and shoulder. On the anterior aspect of the body the ribs are thrust forwards (*i.e.* on the concave side of the curve).

The alteration in the shape of the thorax causes a corresponding alteration in the shape and position of the viscera which it contains.

The condition of scoliosis usually occurs in weak children and debilitated adolescents, but it may be congenital or it may follow acute anterior poliomyelitis (cf. p. 499). It can be distinguished from Pott's disease by the absence of muscular rigidity.

The backward curvature of **Kyphosis**, which occurs in Pott's disease (p. 526), may be caused by constitutional bone disease or occupational postures. It may also occur in rickets, owing to weakness of the muscles of the back.

The forward curvature of **Lordosis** is generally compensatory to flexion at the hip-joint (p. 440).

The **Spinal Medulla (Spinal Cord)** begins at the foramen magnum, where it is continuous with the medulla oblongata, and terminates at or just below the lower border of the first lumbar vertebra. In the infant it is relatively longer and extends to the upper border of the third lumbar vertebra. The segments of the spinal medulla are therefore more crowded together than the corresponding vertebræ, and although the nerve-roots pass horizontally to the intervertebral foramina in the upper cervical region, their course within the vertebral canal becomes longer and more oblique in the thoracic region, while the lumbar and sacral nerve-roots descend almost vertically.

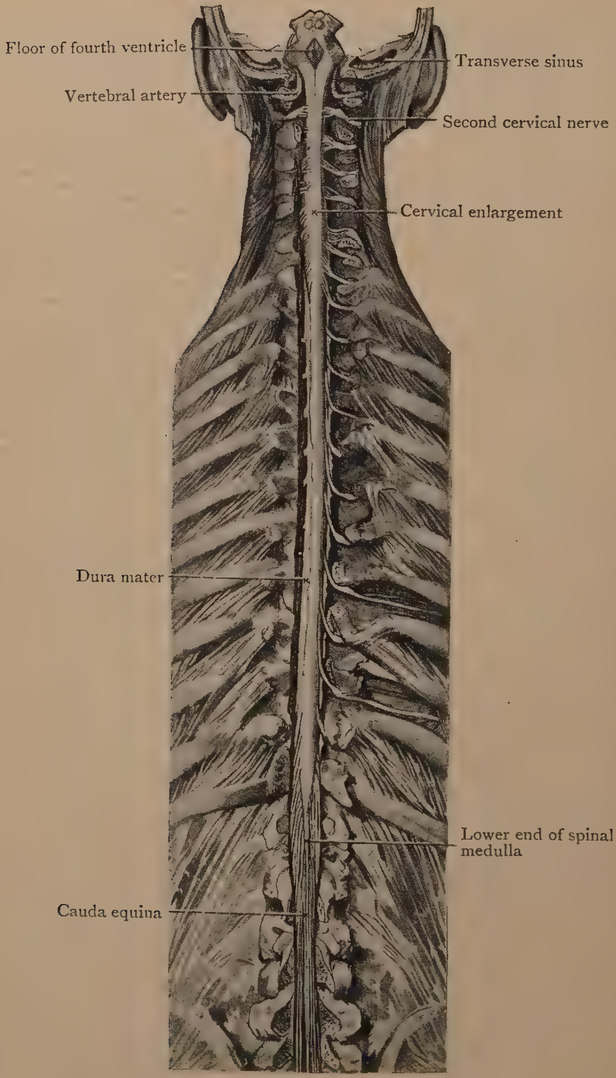
Floor of fourth ventricle
Transverse sinus
Vertebral artery
Second cervical nerve
Cervical enlargement
Dura mater
Lower end of spinal medulla
Cauda equina

FIG. 162.—The Spinal Medulla *in situ*. The dura mater has been partially removed on the right side and two of the intercostal nerves have been traced in a lateral direction.

On transverse section (Fig. 163) it is seen that the grey matter, on each side, is arranged in two columns. The *anterior column* is broad and blunted and contains the motor cells which give origin to the fibres of the anterior nerve-roots. The *posterior column*, which is continuous in front with the anterior column, is somewhat pointed, and near its tip the posterior nerve-roots enter the spinal medulla.

The *anterior nerve-roots*, which are purely motor, emerge from the anterior column of grey matter in series. The *posterior nerve-roots*, which are entirely sensory, enter the spinal medulla in series on its postero-lateral aspect. Each posterior nerve-root possesses a *ganglion*, the cells of which give origin to peripheral and central fibres. In or near the intervertebral foramina the anterior and posterior nerve-roots unite to form a spinal nerve (Fig. 163), and, almost as soon as it is formed, each spinal nerve breaks up into an *anterior* and a *posterior ramus* (*primary division*). The rami, both anterior and posterior, are mixed nerves ; their distribution is dealt with in the various regions of the body.

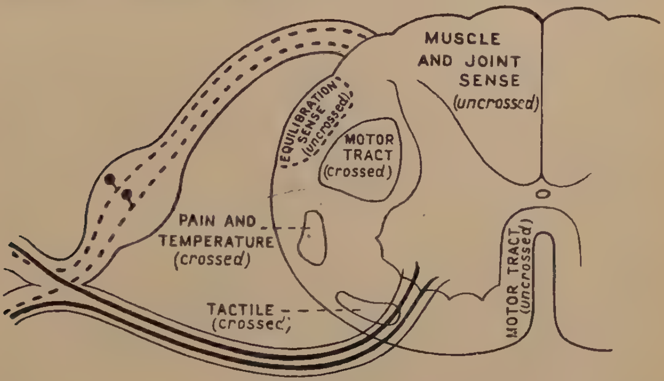
MUSCLE AND JOINT SENSE (uncrossed)
EQUILIBRATION SENSE (uncrossed)
MOTOR TRACT (crossed)
PAIN AND TEMPERATURE (crossed)
TACTILE (crossed)
MOTOR TRACT (uncrossed)

FIG. 163.—Diagram of a Transverse Section through the Spinal Medulla. The anterior (motor) and the posterior (sensory) nerve-roots ; their union to form a typical spinal nerve and their subsequent division into anterior and posterior rami are also shown.

Membranes.—The spinal medulla is surrounded by three membranous sheaths, which are continuous with the membranes of the brain (p. 227). The *pia mater* is closely applied to the spinal medulla and, at its lower end, is continued down as a fine thread, termed the *filum terminale*. The subarachnoid space is continuous with the subarachnoid space in the skull, and it extends downwards to the second sacral vertebra. Below that point the *arachnoid* covers the filum terminale. The *dura mater spinalis* consists of a serous layer only, and is not adherent to the walls of the vertebral canal, to which it is only connected by the spinal nerves. The subdural space, which is really a capillary interval, is only continued downwards to the second or third sacral vertebra, and, below that level, the dura mater spinalis is closely applied to the filum terminale, which eventually blends with the periosteum on the back of the coccyx.

The *Ligamentum Denticulatum* is a membranous sheet which is attached to the pia mater spinalis midway between the anterior and posterior nerve roots from the atlas to the first lumbar vertebra. Its lateral border is serrated and the serrations are attached to the dura in the intervals between the emerging nerve roots. The lowest denticulation can be recognised by its obliquity and is the guide to the roots of L 1, which pierce the dura just below it.

Lumbar Puncture.—The lower part of the sheath formed by the arachnoid and dura mater contains only the lumbar and sacral nerve-roots and the filum terminale, which form a leash, termed the *cauda equina*. In lumbar puncture, advantage is taken of the absence of the spinal medulla from the lumbar part of the vertebral canal to introduce an exploring needle into the subarachnoid space. The operation may be performed in order to withdraw some of the cerebro-spinal fluid for examination, or to inject drugs for the purpose of inducing anæsthesia.

The space between adjoining laminæ is greatest in the lower lumbar region, and on that account either the interval between the third and fourth or that between the fourth and fifth lumbar vertebræ is selected. The patient is placed, preferably, in a sitting posture with the trunk strongly flexed, since the interval between the laminæ is thus slightly increased. The interval between the fourth and fifth lumbar vertebræ corresponds to the line joining the highest points on the two iliac crests, and the site of the puncture lies on this line half an inch from the median plane. A fine exploring needle, fitted with a stilette, is thrust forwards and slightly upwards and medially through the skin, fasciæ, and sacro-spinalis. After passing through the muscle the needle pierces the ligamentum flavum, which connects the laminæ ; the ligament can be readily recognised by the resistance that it causes. The needle then enters the vertebral canal and, piercing the dura mater and arachnoid, gains the subarachnoid space, at a distance of about two inches from the surface. If the instrument has reached the subarachnoid space, withdrawal of the stilette will be followed by the escape of cerebro-spinal fluid.

When the operation is performed for the purpose of inducing spinal anæsthesia, the level of the anæsthesia may be roughly regulated by the position of the patient after the injection. Where it is desired to reach a high level, the patient may be placed flat upon the back, but with the head and neck flexed lest the centres in the medulla oblongata become affected.

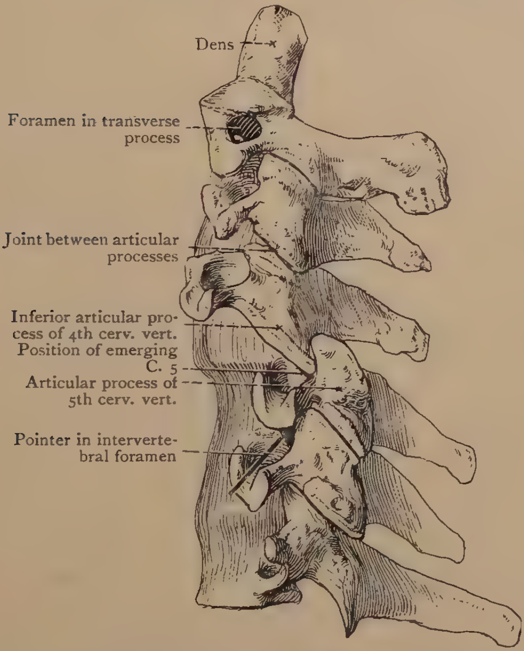
Dens
Foramen in transverse process
Joint between articular processes
Inferior articular process of 4th cerv. vert.
Position of emerging C. 5
Articular process of 5th cerv. vert.
Pointer in intervertebral foramen

FIG. 164.—Unilateral Rotatory Dislocation of the Fourth Cervical Vertebra. The inferior articular process of the fourth cervical vertebra has slipped forwards over the superior articular process of the fifth. In this position it usually presses upon the fifth cervical nerve and causes pain which is referred to the areas supplied by its terminal branches.

Injuries of the Vertebral Column and the Spinal Medulla.—The cervical part of the vertebral column most frequently suffers injury since it normally possesses the greatest range of movement. Slight injuries of the vertebral column may produce serious results owing to the delicate structure of the spinal medulla.

Unilateral, rotatory luxation of an articular process may occur as the result of a sudden twist or bend, and may be partial or complete. In some cases the dislocation may be reduced spontaneously ; in others, the condition may be mistaken for a stiff or sprained neck and the correct diagnosis may be made only after radiographic examination. The inferior articular process slips forwards over the superior articular process of the vertebra below, and it may compress the spinal nerve, giving rise to referred pain over its cutaneous distribution. This injury usually occurs between the third and fourth, fourth and fifth, or fifth and sixth cervical vertebræ, and it may be accompanied by bruising of the spinal medulla and extravasation of blood into or around the spinal medulla (Fig. 164). The resulting sensory and motor changes depend on the extent of the lesion.

Bilateral dislocations are always accompanied by serious injury of the spinal medulla, and, when they affect any of the upper four cervical segments, death is instantaneous, as the diaphragm (phrenic nerve, C. 3, 4, and 5) and the other muscles of respiration are all paralysed.

Fracture dislocation, which is a not uncommon injury, usually occurs in the lumbar or lower thoracic region. The upper vertebra passes forwards and the spinal medulla is crushed between its laminæ and the upper border of the body of the vertebra below. A complete transverse lesion of the spinal medulla generally results, but sometimes the injury is only partial. It may, at first, be impossible to determine whether the lesion is complete or only partial, as in the latter case the amount of paralysis is increased by the pressure of the accompanying extravasation of blood. When the injury is incomplete, gradual improvement occurs as the extravasated blood becomes absorbed. In these cases the motor changes are usually more extensive than the sensory changes.

A *complete transverse lesion* of the spinal medulla is accompanied by total sensory and motor paralysis of the regions which are innervated by the segments below the lesion. As the *upper neurone* is involved, the paralysed muscles are spastic, and although they may atrophy from disuse, they do not give the reaction of degeneration. In the case of the muscles which are innervated by the actual segment destroyed by the injury, the lesion is of the *lower neurone type*. Consequently these muscles rapidly become atrophied, and the reaction of degeneration is present.

If the injury occurs *above the level of the spinal centres for the bladder and rectum* (L. 1 and 2), voluntary control over these viscera is lost and reflex evacuations occur. If the injury occurs at or below the level of these centres, the viscera are paralysed and there is, at first, retention of urine, and, later, a continual overflow. In many cases, however, these centres are only partially affected.

A *complete hemi-lesion* of the spinal medulla causes complete paralysis of the muscles of the same side of the body which are innervated by the segments below the lesion. Sensory changes also occur, but, as all the fibres which convey painful and thermal sensations cross the middle line immediately they enter the spinal medulla, and as those which convey tactile and pressure sensations cross only a few segments above their point of entry, changes in protopathic sensibility are found, almost exclusively, on the opposite side of the body. Epicritic sensibility and sensations of movements and of posture, however, are conveyed by fibres which ascend on the same side till they reach the medulla oblongata, where they decussate. These sensations therefore are only lost in the paralysed limb. A narrow zone of anæsthesia is present at the upper limit of the motor paralysis. In this situation the sensory fibres are involved as they enter the spinal medulla and the position of the anæsthetic strip is a certain indication of the site of the lesion. Immediately above the zone of anæsthesia there is usually a narrow zone of hyperæsthesia.

Complete destruction of the spinal medulla at the level of the fifth cervical segment is consistent with life, since the nerve-supply to the diaphragm (phrenic nerve, C. 3, 4, and 5) is not at once destroyed. This lesion is accompanied by total paralysis, of the upper neurone type, of the trunk and all the limbs. The sensory paralysis does not extend so high on the anterior surface as it does on the posterior surface of the body. Anteriorly, the *line of anæsthesia* corresponds to the second costal cartilage, as the skin above that level is supplied by C. 3 and 4 (Fig. 72). Posteriorly, the line lies at a higher level, since the posterior rami of the third and fourth cervical nerves do not extend so far downwards as their anterior rami (Fig. 3). This condition is usually followed by an ascending myelitis, which destroys the spinal centres of the phrenic nerve, causing death in a few days.

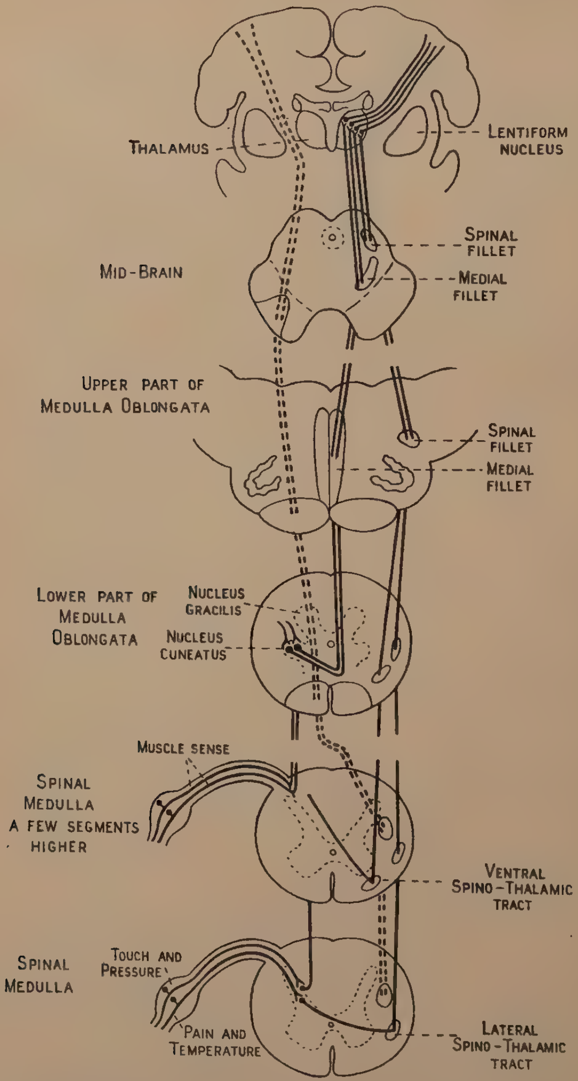
THALAMUS
LENTIFORM NUCLEUS
MID-BRAIN
SPINAL FILLET
MEDIAL FILLET
UPPER PART OF MEDULLA OBLONGATA
SPINAL FILLET
MEDIAL FILLET
LOWER PART OF MEDULLA OBLONGATA
NUCLEUS GRACILIS
NUCLEUS CUNEATUS
MUSCLE SENSE
SPINAL MEDULLA A FEW SEGMENTS HIGHER
VENTRAL SPINO-THALAMIC TRACT
SPINAL MEDULLA
TOUCH AND PRESSURE
PAIN AND TEMPERATURE
LATERAL SPINO-THALAMIC TRACT

FIG. 165.—Diagrammatic Representation of the paths of the Chief Motor and Sensory Tracts. The motor path is indicated by the dotted lines. Note that the fibres conveying painful and thermal sensations cross to the opposite side at the same level as they enter the spinal medulla, whereas those conveying pressure and tactile sensations ascend for a few segments before they do so.

When the sixth cervical segment is destroyed, the muscles supplied by C. 5, being unopposed, produce a characteristic attitude. The upper limbs are abducted and laterally rotated at the shoulder, the forearm is flexed and supinated. An ascending myelitis usually occurs, and destruction of the fifth segment is indicated by the collapse of the upper limbs upon the trunk.

In transverse lesions of the spinal medulla occurring between the fourth cervical and the second thoracic segments the limit of anæsthesia on the anterior surface of the body is placed at the level of the second costal cartilage (p. 4). The distribution of the areas of altered sensibility in the upper limbs gives an indication of the exact level at which the spinal medulla is injured. *When a lesion occurs below the second segment in the thoracic region,* the upper limit of the anæsthesia corresponds to a horizontal line drawn round the trunk at the level of the terminal branches of the intercostal nerve which arises from the injured segment. As the thoracic nerve-roots pass downwards before they leave the vertebral canal, and as the nerves subsequently descend for some distance before they terminate (p. 244), the site of the injury to the vertebral column is placed at a much higher level than the upper limit of the anæsthesia.

A complete transverse lesion of the spinal medulla in the lower thoracic region is accompanied by total motor and sensory paralysis of both lower limbs. Although the lesion in the vertebral column is above the level of the transpyloric plane, the muscles of the abdominal wall, which are supplied by the seventh to twelfth thoracic nerves, are little affected, and the cutaneous sensibility is altered only in the lowest part of the wall. Reflex evacuations of the bladder and rectum occur, as the lesion is above the level of the spinal centres for these viscera (p. 537).

In *complete transverse lesions above the level of the seventh thoracic segment* all the muscles of the abdominal wall are paralysed and the condition of *meteorism* supervenes; owing to the absence of the expulsive force, gas accumulates in the alimentary canal and the abdomen becomes greatly distended.

Fracture dislocation in the lumbar region of the vertebral column involves the cauda equina. All the nerve-roots of the cauda are rarely affected, and the alteration of sensibility in the saddle-shaped area supplied by the third sacral nerves (Fig. 116) is usually asymmetrical. As the condition arises from a root injury, the area of epicritic loss is smaller than the area of protopathic loss (p. 97). In these cases the bladder and rectum are often affected, but the paralysis is rarely complete.

Fracture of the Articular Processes alone does not necessarily give rise to symptoms of nerve pressure.

Surgical Approach to the Spinal Medulla.—It may be necessary to expose the spinal medulla in order to remove the cause of pressure, when it is being compressed, or to divide the posterior nerve-roots, in intractable neuralgia (the " crises " of locomotor ataxia).

A vertical incision is made in the median plane and is carried down to the vertebral spines. The muscles attached to the spines and laminæ are elevated on both sides, and this step may give rise to severe hæmorrhage. The bleeding, however, may be controlled by packing tightly with gauze and forcibly retracting the muscular masses in a lateral direction. The supra- and inter-spinous ligaments of the vertebra selected are cut and the lamina on each side is divided with an osteotome. The instrument is applied with its cutting edge *at right angles to the inferior border of the lamina.* In this way there is no danger of cutting into the root of the vertebral arch (pedicle), and, if the instrument slips when the division of the lamina is completed, the spinal medulla cannot be injured.

After both laminæ have been divided, the ligamenta flava (p. 534) are cut across, and the vertebral arch may be removed. Additional laminæ can then be removed with bone forceps. Some loose fatty tissue containing numerous small veins is exposed on the surface of the dura mater. The hæmorrhage from these veins may be so great as to necessitate a two-stage operation.

The dura mater is incised, and as the arachnoid may be injured at the same time, cerebro-spinal fluid may escape in company with subdural fluid. To prevent too great an outflow the head-end of the table should be depressed.

When the operation has been completed, the cut edges of the dura mater are carefully united (p. 543) and the thick muscular flaps are replaced.

Development of the Nervous System and the Vertebral Column.—During the second week of intra-uterine life, a longitudinal furrow, termed the *neural groove*, appears on the dorsal aspect of the embryo. The walls and floor of this groove are formed by a thickening of the surface ectoderm. At a slightly later stage the margins of the groove unite and it becomes converted into the neural tube, which subsequently gives origin to the whole of the nervous system. At first the dorsal part of the neural tube is continuous with the surface ectoderm, but the two soon become separated by mesoderm, which grows in from each side.

The mesoderm which surrounds the neural tube forms the vertebral column and the membranes of the brain and the spinal medulla. *Two bars of cartilage* appear in each segment, one at each side of the neural tube, and grow backwards to form the vertebral arch. They fuse with one another dorsally during the fourth month and enclose the neural tube, surrounded by a sheath of mesoderm, which becomes differentiated into the dura mater, arachnoid, and pia mater.

The cartilaginous bars may fail to fuse on the dorsal aspect of the neural tube. This condition, which is termed *spina bifida*, most commonly occurs in the lumbo-sacral region and may affect several consecutive segments. It is usually associated with anomalies of the spinal medulla and its membranes, but it may occur alone—*spina bifida occulta.*

The anomalies associated with spina bifida are subdivided into several varieties, and the precise nature of the anomaly can rarely be determined until the sac of the tumour which it forms is opened.

1. In a **Meningocele** the spinal medulla is normal in development and position, and it possesses a complete covering of pia mater. The arachnoid and the dura mater form a hernia, filled with cerebro-spinal fluid, which projects backwards through the deficiency in the vertebral arches and forms a tumour under the skin of the back. Sometimes the dura mater is deficient dorsally and the sac of the tumour is formed solely by the arachnoid (Fig. 166, *a*): at others, the arachnoid maintains its normal relationship to the spinal medulla and the sac is formed by the dura mater alone.

2. The **Myelo-Meningocele** differs from a meningocele in that the spinal medulla, though normally developed and covered by pia mater, herniates backwards into the sac of the tumour. Both the spinal medulla and the nerve-roots arising from it may be adherent to the inner wall of the sac (Fig. 166, *b*).

3. In a **Myelo-Cystocele** the central canal of the spinal medulla is enlarged in a backward direction, and its thin dorsal wall, which retains its primitive embryonic structure, projects through the deficiency in the vertebral arch. The dura mater

is said to be completely absent over the dorsal surface of the tumour and the arachnoid is in contact with the skin (Fig. 166, *c*).

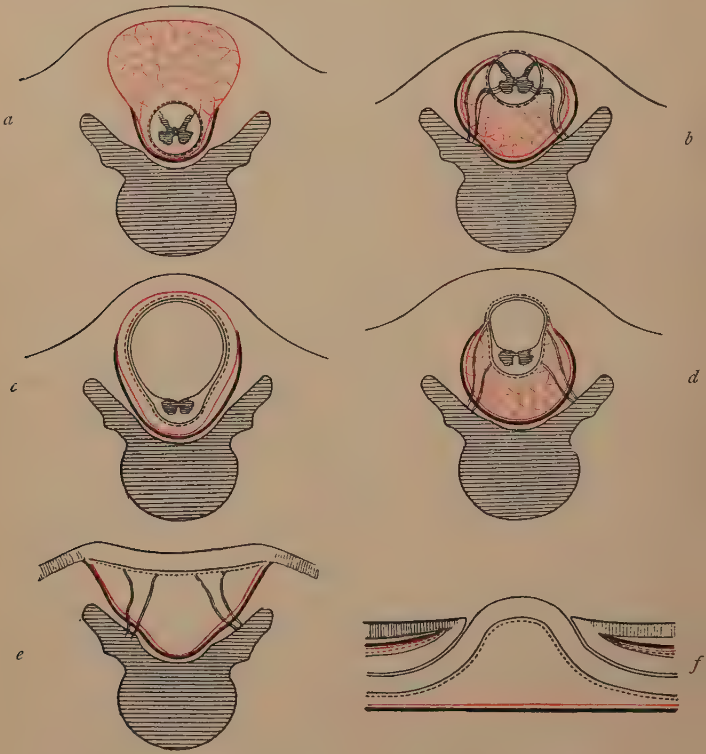

FIG. 166.—Diagram illustrating some of the Congenital Anomalies of the Vertebral Column and Spinal Medulla.

a. Meningocele.	*d.* Myelo-cysto-meningocele.
b. Myelo-meningocele.	*e.* Myelocele, transverse section.
c. Myelo-cystocele.	*f.* Myelocele, longitudinal section

The dotted line represents the pia mater, the red line the arachnoid, and the heavy black line the dura mater.

a, *b*, *c* and *d* show the un-united vertebral arches on transverse section.

In *e* and *f* the vertically shaded areas represent the skin.

In *f* the central canal of the spinal medulla is seen opening on the surface at the upper and lower limits of the myelocele.

4. In a **Myelo-Cysto-Meningocele** the condition is similar to (3), but, in addition, the subarachnoid space is greatly dilated and forms an arachnoidal meningocele.

Note.—In arachnoidal meningoceles, whether simple or complicated by myelo-cystoceles, fine strands are frequently found in the subarachnoid space, connecting the arachnoid to the pia mater. These strands may be not unlike spinal nerves.

5. A **Myelocele** is due to an arrest of development at the time of the closure of the primitive neural groove. In a limited area the edges of the groove fail to unite and the central canal of the spinal medulla opens on the dorsal surface of the fœtus. The exposed area, which is elliptical in shape and brownish in colour (the "area medullo-vasculosa" of Recklinghausen), consists of a flattened zone of neuroglia containing a few nerve-cells. Rudimentary anterior and posterior nerve-roots are attached to the ventral surface of the undeveloped part of the spinal medulla. Complete paralysis is present on both sides of the body below the level of the anomaly. As the central canal of the spinal medulla opens on the surface (Fig. 166, *f*), septic infection rapidly occurs and death results shortly after birth. These cases are therefore unsuitable for treatment.

In the other varieties described the sac may be exposed by a longitudinal incision, which divides to surround the tumour. When the tumour is situated in the sacral region, a transverse incision may be employed in order to keep the wound as far as possible from the anus. On the dorsal aspect of the tumour the skin is extremely thin over an area of variable extent, and this pellicle is enclosed by the incision. The skin is undercut on each side and the wall of the sac is opened. The subsequent treatment depends on the precise nature of the tumour.

In simple meningocele, part of the sac is removed and the edges are carefully approximated. In myelo-meningocele the spinal medulla and nerve-roots are freed, if adherent to the inside of the sac, and are then replaced within the vertebral canal. Part of the sac is removed and the wound is closed in two layers—sac wall and skin.

In order to prevent leakage of the cerebro-spinal fluid, the cut edges of the sac wall are turned backwards and their inner surfaces are carefully stitched to one another. In myelo-cysto-meningocele, part of the sac may be ligatured and removed, but, in this case also, great care must be taken to prevent subsequent leakage of cerebro-spinal fluid.

Similar deformities occur in connection with the skull and the membranes of the brain, but they are much rarer. *Cranial meningocele*, *encephalocele*, and *hydr-encephalocele* correspond respectively to spinal meningocele, myelo-meningocele, and myelo-cysto-meningocele. They are usually found in the median plane, and their commonest site is below the external occipital protuberance in the occipital region.

A hydr-encephalocele in the occipital region contains the herniated dorsal wall or roof of the fourth ventricle. When the tumour occurs in the line of the frontal (coronal) suture it contains a diverticulum from the lateral ventricle.

The sac of the tumour is covered by skin, normal or thinned, and it consists of arachnoid, save in simple meningoceles, where the dura mater may be present. The sac is opened in order to ascertain whether it contains any brain tissue (encephalocele or hydr-encephalocele) or merely cerebro-spinal fluid (meningocele). If brain tissue is found and cannot be reduced within the skull, it may be ligated and removed. In suturing the cut edges of the membranes care must be exercised to prevent subsequent leakage of the cerebro-spinal fluid.

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